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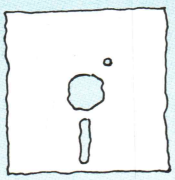

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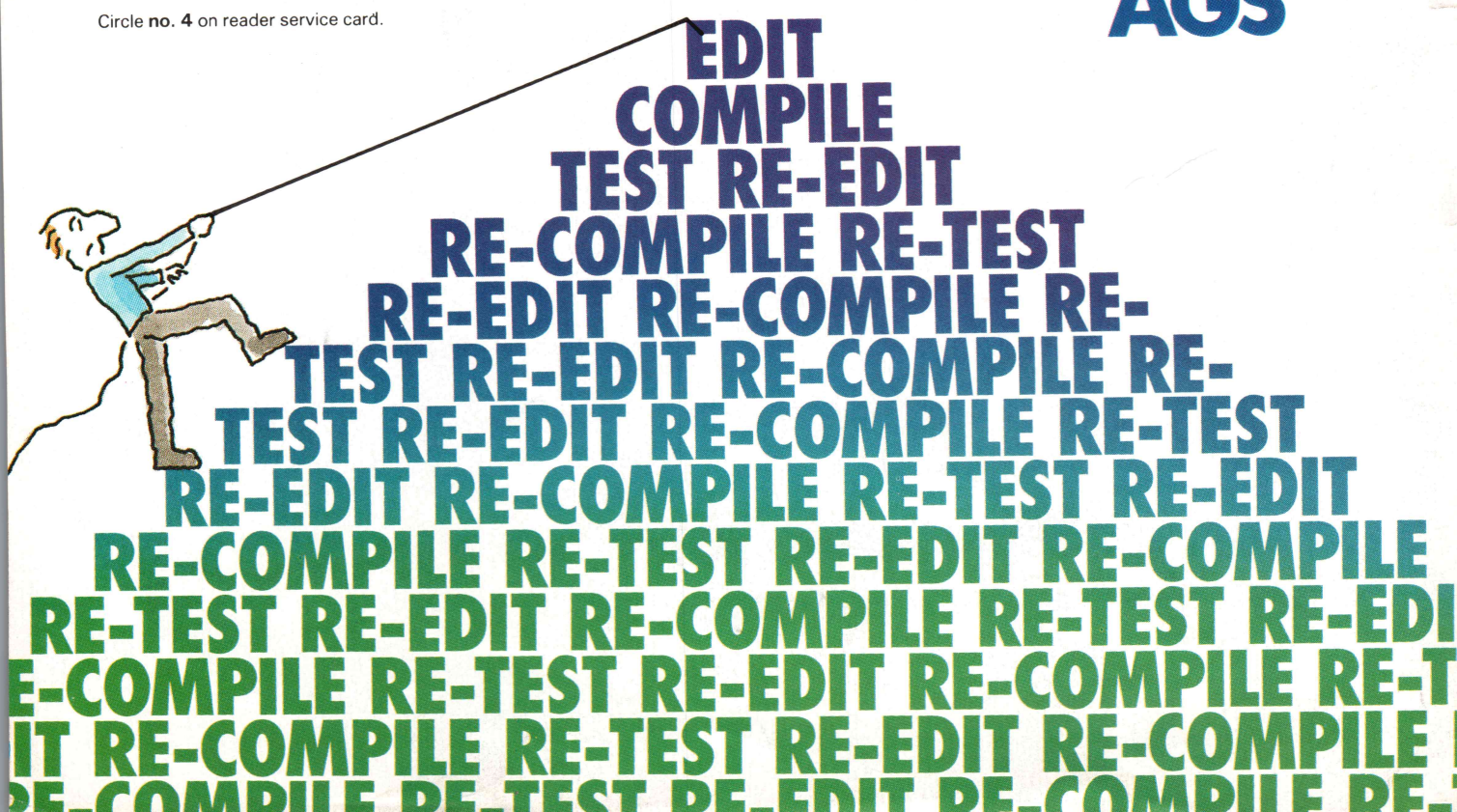

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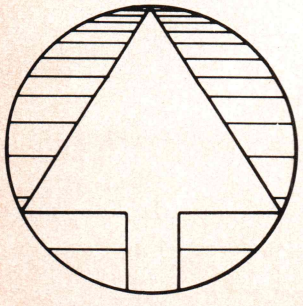

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August 1985
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This Month

This month *DDJ* focuses its attention on C. The issue should contain a little something for everybody. One "little something" for all our readers is Jim Hendrix' "Small-C Update." After reading this latest chapter in the story of the compiler first published in the pages of *Dr. Dobb's*, MSDOS C programmers can go straight to the review of MSDOS C compilers, while CP/M C programmers can flip to David Fox' article on optimizing assembly language output from the Software Toolworks' C/80. Unix gurus, on the other hand, will probably want to turn to this month's C Chest, where they can find an MSDOS version of one of their favorite Unix utilities, make. We hope you will find something you like.

Writers' Guidelines

What are the topics on which *DDJ* would like to receive articles? What style of writing is appropriate to *DDJ*? How should I format my text? How should I format listings and how extensively should I comment them? Should I submit hard copy of my manuscript, or a diskette, or both? How much will I get paid for my contribution? The answers to these and other frequently-asked questions can be found in the latest revision of the Writers' Guidelines for *Dr. Dobb's Journal*. To obtain a copy along with the current editorial calendar, drop us a note.

This Month's Referees

Richard Relph, ELXSI
Richard G. Larson, University of Illinois at Chicago
James Hendrix, University of Mississippi

Dr. Dobb's Journal

ARTICLES

C Compilers for MSDOS — 30
by the PicoNet C-SIG and the SVCS
The C-SIG and SVCS have assembled a suite of 30 benchmarks, run them through the most popular MSDOS compilers and interpreters and tabulated the results. **(Reader Ballot No. 191).**

A Peephole Optimizer for Assembly Language Source Code — 56
by David L. Fox
Using regular expressions you can optimize the output of any compiler producing assembly language code. **(Reader Ballot No. 192).**

Small-C Update — 84
by James Hendrix
An update on the compiler first published in the pages of *DDJ*: bug fixes, improvements and MAC, a new Small-C macro assembler. **(Reader Ballot No. 193).**

Asynchronous Protocols — 92
by David W. Carroll
A description of the features, strengths and weaknesses of the most popular asynchronous protocols in use today. **(Reader Ballot No. 194)**

COLUMNS

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DRI Generic Sales; the Z80; nesting MSDOS; quasi random number generators. **(Reader Ballot No. 190).**

C Chest — 96
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16-Bit Software Toolbox — 116
by Ray Duncan
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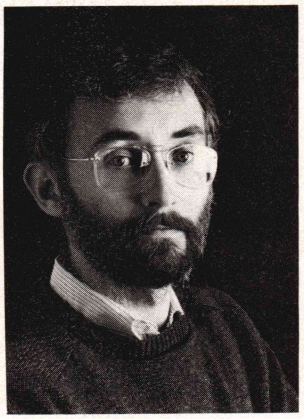
EDITORIAL



We'd like to congratulate Microsoft, Lifeboat, and PC World for their jointly-sponsored C-85 conference in San Francisco in May. All the *DDJ* editorial staff attended (Allen Holub, our C columnist, and Richard Relph, coordinator of the C compiler review in this issue, were among the speakers), and we found it educational and well-planned.

One session was of particular interest to us. At a discussion of compiler and library evaluation and benchmarking, a speaker chastised computer publications for the inadequacy of their technical reviews. We sat in the audience nodding in agreement.

It's true: today's computer magazines typically do not provide adequate information to permit software developers to choose one compiler or programming tool over another. A relatively conscientious reviewer may (1) run three benchmark tests, usually a floating-point test, the Fibonacci and the Sieve of Eratosthenes; (2) list the product's features; and (3) give a clear picture of his own experiences in using the product. Most do less.

The C-85 conference session pointed out the need for a higher level of criticism, at least in the evaluation of technical products. This is an area in which the vendors and customers are both highly knowledgable. Programmers and system designers read reviews for solid information on which to base decisions affecting their livelihoods. Vendors deserve an accurate appraisal of their products in terms that matter to their customers.

A useful compiler review should, we think, assess completeness, correctness, adherence to standards, and use a widely-available suite of benchmarks applied in a repeatable manner to measure all the major aspects of compile- and run-time performance. Publication of a review should constitute a commitment to continue to evaluate the product, and to publish updates and corrections when appropriate. And no review should be the work of a single individual, no matter how knowledgable or above reproach.

We've tried to provide such a useful review in this month's evaluation of 13 C compilers, done by over a dozen programmers using several dozen benchmarks, with several pairs of eyes reading the manuscript. But we don't claim we brought it off flawlessly, and we'll be following up on this review with updates, corrections (if necessary), and comparable benchmark results for other compilers.

For us, and we think for computer publications generally, this is new ground. we don't believe that any computer magazine has been doing technical reviews the way they should be done, and that includes *Dr. Dobb's Journal*. We hope to change that, and this issue's C compiler review is one step in that direction.

We plan to take some more steps in the direction of useful reviews in the coming months. One desirable feature that this month's C compiler review lacks is a single benchmark test providing a real-world mix of functions; we're looking into some tests that purport to do this. We welcome your feedback and suggestions.

Michael Swaine

Michael Swaine

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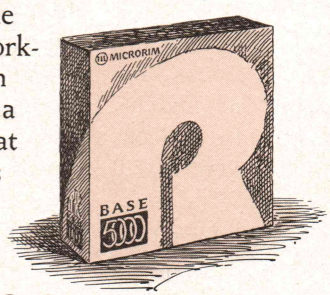

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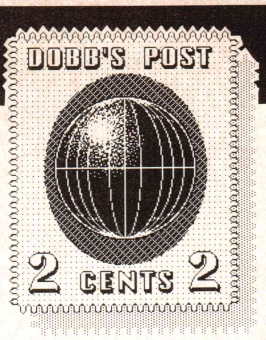

Tiny BASIC

Dear *Dr. Dobb's*:

I read with great interest the article "Tiny BASIC for the 68000," which ran in the February 1985 issue of your magazine. I have been a long-time 68000 programmer and have written a full BASIC interpreter for the machine. But, dear Doctor, a 68000 BASIC only about 10% faster than a Z80? I quickly got a copy of the source from the bulletin board and started probing. Mr. Brandly did a nice job of coding, but he missed a few tricks. It is relatively easy to do a substantial speed-up without increasing size significantly or changing any outward functionality.

The main problem in this BASIC implementation is the TSTC subroutine. TSTC compares the current character against a test value and branches to a specified location if they do not match. TSTC gets used a lot in even simple statements; 10 X=1 (crlf) calls it 7 times. I count 98 clocks for TSTC if the characters match, and 102 clocks if they do not match. Inline code to replace TSTC could be made a macro as follows:

```
TSTC  MACRO
      BSR IGNBLK
      CMPI.B #'&1',(A0)
      BNE &2
      ADDQ.L #1,A0
      ENDM
```

which executes in 46 clocks (for match) and 40 clocks (no match). This gives a savings of 52 to 62 clocks per use of TSTC . . . or almost 400 clocks in a simple assignment statement. Any statement involving an expression will see a similar (or greater) improvement.

The second improvement also occurs in the expression evaluator routine EXPR. (This is where most improvements are to be found, since expression evaluation is key to the interpreter's performance.) EXPR uses the EXEC subroutine to check for relational operators (=,<,>,<=,>=). EXEC is a table-searching routine normally used to check for keywords. It includes a lot of overhead to check for shorthanded keywords that can never occur in relationals. Also, the most usual case—no relational—requires searching the six possible relationals first before discovering the default condition. My suggested improvement treats relational operators as a special case, removing them from the EXEC tables and substituting the code in Listing One (page 16) for the EXEC call at the top of EXPR. Note that the default case (no relational) now takes only three compares. This is significant because it is used every time an expression (number, variable, etc.) is encountered.

The third improvement is found in the find-lines routines: (FNDLN, FNDLNP, FNDNXT, and FNDSKP.) These routines find heavy usage in GOTOs, GOSUBs, and IFs. The point here is that the original coding resets register A2 to the end of the program text for each line. This 24 clock overhead per line can be saved by a little re-ordering and a few extra bytes Listing Two, page 16.)

My final improvements do not affect the execution speed of the interpreter, but rather speed up program editing. The block-move subroutines MVUP and MVDOWN can be speeded up quite a bit at the cost of some additional code. I'll illustrate with MVUP. It is currently coded:

```
MVUP   CMP.L A1,A3
       BEQ MVRET
       MOVE.B
         (A1)+,(A2)+
       BRA MVUP
*
MVRET RTS
```

This requires 36 clocks per byte moved. If one calculates the number of bytes to be moved outside the loop, a much tighter inner loop (22 clocks per byte) is possible (see Listing Three, page 17). The set-up overhead is 48 clocks, so it takes only 4 cycles through the inner loop to outweigh it. This version of MVUP can handle a maximum of 65,536 bytes (the original had no restriction), but this should not prove much of a problem in Tiny BASIC programs.

A final note to the Doctor: please keep articles like this coming! There is nothing that improves the "breed" of programmers like quality examples. Thank you.

Sincerely yours,
Robert D. Grappel
28 Buckmaster Drive
Concord, MA 01742

Ellipses

Dear *DDJ*,

Many thanks to Tom Hogan for his excellent derivation of the DV (decision variable) method for plotting ellipses. His explanation of this potentially confusing subject is very clear. This general approach, sometimes called 'displacement comparison' appears elsewhere in the literature, but this is the first time I have seen it applied to ellipses.

I would like to point out a minor error in the derivation, and then show how the full potential of the method can be achieved by one more refinement that eliminates all multiplication within the loops.

The error is in Equation 10. If the x-axis is the major axis, the initial point is at

$$(0, \sqrt{\frac{\beta}{\alpha}}\ R_m), \text{ not } (0, \frac{\beta}{\alpha}\ R_m)$$

Equation 10 is correct if the first term is changed to reflect this. The

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situation is clarified if one considers a different form of the equation of the ellipse:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

where a and b are the radii along the x the y axes, respectively.

If we let $\alpha = a^2$ and $\beta = b^2$, then Mr. Hogan's Equation 1 is equivalent. It is clear that the aspect ratio is b/a, and Mr. Hogan's use of the aspect ratio is consistent, except for equation 10. If the x-axis is the major axis, then $R_m = a$, and the initial point is at b, which is given by $R_m \times$ aspect ratio, or $R_m \times (b/a)$. (We are assuming that the center of the ellipse is at (0, 0)). This is a fairly obvious error, but it could confuse the unwary (me, for example). The statement in the program which initializes d is correct, so I assume Mr. Hogan found the error and simply overlooked this one instance.

Much more interesting is an examination of the operations that are performed within the loops for computing successive dot locations. An example is the computation of 'd' at the end of the first loop

```
(d += two_beta *
   (3 + (rel_x << 1)) )
```

Note that every term in the computation is a constant except for rel_x, and further, that rel_x is incremented by exactly one every time the loop is executed. So let's rewrite that line for clarity:

```
(d += two_beta*3 +
   two_beta*rel_x*2)
```

or in human rather than computer math

$$(d += 6\beta + 4\beta \text{xrel})$$

Now we will cleverly initialize our added variable d_norm to 2β before entering the loop, so every pass we add 4β to d_norm before adding it, in turn, to the former value of d.

All of the multiplication operations within the loops can be replaced by additions in a similar way, as demonstrated in Listing Four (page 18) (we use x, y in place of rel_x, rel_y to denote the local coordinates relative to the center of the ellipse, and we don't bother to maintain the global coordinates row and col, but the result is the same).

I will be happy to discuss this with anyone who wants to call me at (206) 226-3916, or via IEEE COMPMAIL—user name eric.therkelsen.

Again, many thanks to Mr. Hogan for a derivation that is a significant contribution to the literature.

Sincerely,
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Prolog

Sirs:

I enjoyed your March, 1985, issue on Prolog, but thought I should write to warn your other readers of possible support problems with Programming Logic Systems, Inc., the U.S. marketers of MicroPROLOG. Over the past 5 months I have attempted, with no success whatsoever, to obtain the simple information whether there have been any changes or upgrades to the software in the year or so since I purchased it. Neither the U.S. or British offices will respond to repeated mail inquires (the British office simply sent a brochure, in no way answering my very simple question). If these people can't respond to a question as simple as that, it does not bode well for their willingness to respond to substantive inquiries, and suggests to me that one of the other fine implementations of the language would be a better choice.

Sincerely,
George Carey
2048 Winding Creek Ln.
Marietta, GA 30064

DDJ

Letters (Text begins on page 10)

Listing One

```
        BSR IGNBLK              skip blanks
        MOVE.B (A0)+,D2         get first char.
        CMPI.B #'=',D2          equals?
        BEQ XP15                yes, process it
*
        CMPI.B #'>',D2          >, or >= ?
        BNE XXP1                no
*
        CMPI.B #'=',(A0)        >=?
        BNE XP13                no, process >
*
        ADDQ.L #1,A0            skip past =
        BRA XP11                process >=
*
XXP1    CMPI.B #'<',D2          <, <=, or <>?
        BEQ XXP2                yes
*
        SUBQ.L #1,A0            no, default case
        BRA XP17                handle default
*
XXP2    CMPI.B #'=',(A0)        <=?
        BNE XXP3                no
*
        ADDQ.L #1,A0            yes, skip past =
        BRA XP14                process <=
*
XXP3    CMPI.B #'>',(A0)        <>?
        BNE XP16                no, process <
*
        ADDQ.L #1,A0            skip past >
        BRA XP12                process <>
```

End Listing One

Listing Two

```
FNDLN   CMPI.L #$FFFF,D1
        BCC QHOW
        MOVE.L TXTBGN,A1
        MOVE.L TXTUNF,A2        note change
        SUBQ.L #1,A2
*
FNDLNP  CMPA.L A1,A2
        BCS FNDRET
*
        MOVE.B (A1),D2
        LSL.L #8,D2             note change
        MOVE.B 1(A1),D2
        CMP D1,D2
        BCC FNDRET
```

```
*
F1      ADDQ.L #2,A1            note change
F2      CMPI.B #CR,(A1)+
        BNE F2
*
        BRA FNDLNP
*
FNDNXT  MOVE.L TXTUNF,A2        note change
        SUBQ.L #1,A2
        BRA F1
*
FNDSKP  MOVE.L TXTUNF,A2        note change
        SUBQ.L #1,A2
        BRA F2
```

End Listing Two

Listing Three

```
MVUP    MOVE.L D0,-(SP)         preserve D0
        MOVE.L A3,D0
        SUB.L A1,D0             compute no. of bytes
        BLE MVRET               no bytes?
*
        SUBQ.L #1,D0            adjust for DBRA
*
MV2     MOVE.B (A1)+,(A2)+
        DBRA D0,MV2
*
MVRET   MOVE.L (SP)+,D0         restore D0
        RTS
```

End Listing Three

(Listing Four begins on next page)

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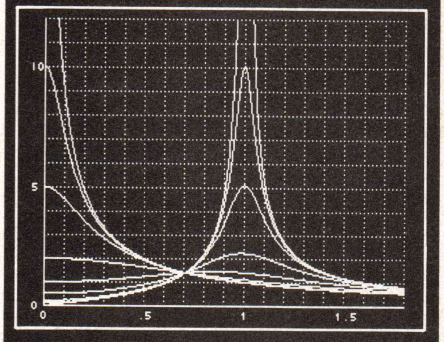

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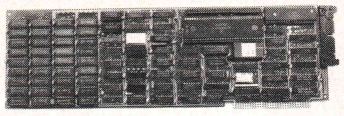

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Letters (Listing continued, text begins on page 10)

Listing Four

```
ellipse_write ( xc, yc, a, aspect )
    int xc, yc, a;
                /* xc, yc are coords of center; a is radius along x-axis */
                /* we chose to input a rather than Rm */

    float aspect;
    {
    long alpha, beta;
    long four_alpha, four_beta, alpha_y, beta_x, d, d_exc, d_norm;
    int b, Rm;     /* b is radius along y-axis */
        /* since a is not necessarily the major radius, we will compute Rm */

    int  x, y;          /*    local coords relative to center of ellipse    */
                                .
                                .

            [ initialization similar to Mr. Hogan's ]

                                .
                                .

    alpha_y = alpha * y;     /* new vbls to avoid multiplication in loop...*/
    beta_x = 0L;
    d_exc = - four_alpha * y;
    d_norm = beta << 1;

    d = 2*alpha*(y*(y-1)) + alpha + 2 * (beta - beta*Rm - alpha*beta);
            /* This is Mr. Hogan's original statement - it is correct
               even though equation 10 is not.    */

    while ( alpha_y > beta_x )
        {
        put_dots ( xc, yc, x, y );
        if ( d >= 0 )
            {     /*    exception condition - decrement y occasionally    */
            d += ( d_exc += four_alpha );
            alpha_y -= alpha;
            y--;
            }
        d += ( d_norm += four_beta ) ;     /*    always increment x    */
        beta_x += beta;
        x++;
        }

    /*    slope is now < -1, so proceed with rest of ellipse    */
                                .
                                .

                    [ 'nuff said? ]
                                .
                                .
```

End Listings

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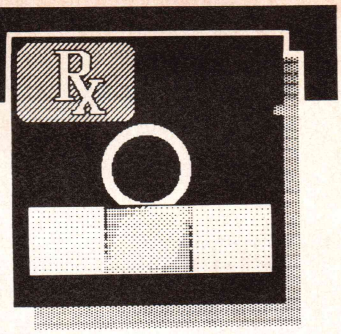

by D. E. Cortesi

DRI Generic Sales Again

Barry Watzman writes to contradict us regarding Digital Research's policy on selling generic operating systems. He claims that DRI is "not only not selling generic systems any longer, they are no longer licensing value-added vendors either. The new rule is, if you're not the manufacturer of the computer on which the implementation will run, forget it."

By way of proof, he sent along a photostat of a letter to him from Alice Clark, Contract Administrator at DRI. It includes the sentence: "We are not currently licensing companies to modify and redistribute our software unaccompanied by hardware or an application program."

The dispute seems to be over how much and what kind of value a "value-added" vendor must add to be acceptable. Watzman wants to make a business of configuring DRI systems to Zenith hardware (he does it very well from all we hear). DRI's position, he says, prevents it.

What Z800?

Roger Smith was turning over back issues of *DDJ* when his eye was caught by the confident words of L. Barker in this column for November 1981. "When the Z800 comes out next year," Barker averred, "with the Z80 instruction set and multiply and divide, this [worrying about the speed of arithmetic] will look like a waste of time."

That pin-compatible Z80 superchip never appeared, so far as we know. "Does anybody know what happened?" Smith wonders, and so do we.

Nesting MSDOS

Remember how we finally got CP/M batch command processing pretty well fixed up? If you don't, you might like to refer to these old Clinics:

June 1982 for PAUSE and BEEP commands
August 1982 for null-line, lowercase, and control character fixes
September 1982 for the QUITIF program
October 1982 for nested submits
January 1984 for a PAUSE that works in CP/M Plus

You might think that batch execution in MSDOS Version 2 wouldn't need our help, but you'd be wrong: MSDOS won't nest batch files. When you invoke a batch file in a batch file, the called file replaces its caller instead of being its subroutine.

We just discovered how to do it. You nest batch files by nesting command shells. Command.com, the shell, can be named as a command. If given a /c switch, it executes the single command that follows on the command line and ends. If that command is a batch file, it will be executed in full, and control will return to the calling batch file. Type in our demo file, recurse.bat (Listing One, page 24), and try it out with a line like

```
recurse 0 1 2 3 4 5
```

What's nice is that each level of command.com has its own environment. The nested batch file can do all the sets and paths it likes; on exit, the prior environment is restored. Add a chkdsk command to the end of the file to see how much space each nesting level takes up.

Random Error

In February, we published a quasi-random number generator (QRNG) credited to persons named Talley and Metropolis (about whom we know nothing more). Ever since then, we've been backing away from it, but we have the subject more or less under control now, mostly thanks to David Ross and Michael Barr.

We showed the QRNG in C. It had two main parts. The first, rand0( ), purported to produce quasi-random numbers uniformly distributed between zero and MAX. Take that at face value; we'll come back to it.

The second part, randi(*u*), used the first to produce what purported to be quasi-random numbers uniformly distributed between 1 and *u*. It did not. Here's the essence of how we coded it:

```
randi(u)
unsigned u;
{
    return(1 + rand0( ) % u);
}
```

The percent sign is the C sign for modulus. Can you see what's wrong with this?

Michael Barr and Peter K. Pearson did. Barr put it best: "Imagine you adopted the following method to find random digits from 0 to 9: throw a dart at the face of a clock and take the low-order digit of the number nearest to where the dart hits. It is evident that you will get the digits 1 and 2 one time in six and the other digits once in twelve. Thus a random event is translated into one that is still random, but not uniformly distributed. [Your procedure randi(*u*)] does that. It shows up most clearly when *u* is a sizable fraction, say 2/3, of MAX. In that case, you will get approximately twice as many values between 0 and *u* /2 as between *u* /2 and *u*."

We devised randi( ) with the vague mental image of how the mod function folds the real number line, like a carpenter's rule, into a heap of *u*-sized segments. And so it does, but

the short last piece improperly enriches the low end of the range. What randi( ) really wants to do is to rescale the range 1 . . . MAX to fit in the interval 1 . . . *u*. Rescaling calls for, not mod, but division, like this:

```
randi(u)
unsigned u;
{
  return(1+ rand0( )*u/MAX);
}
```

But there are problems implementing that. The main charm of these routines was that they worked with 16-bit integers. The expression *u* /MAX is a fraction; if we do rand0( )**u* first, its result will exceed 16 bits.

Now, rand0( ) makes use of two constants: MAX0 and MAX. MAX0 is usually 2^w, while MAX = MAX0–1. In our original version, *w* was 15, but clearly it should be the word size of the computer, usually 16. Supposing that to be the case, the expression

```
rand0( )*u/MAX0
```

can be implemented cheaply enough by doing a 16-bit unsigned multiply and taking the most significant 16 bits of the 32-bit result. Picture it as using multiplication by *u* to squeeze out some of the high-order bits of rand0( ).

The right scaling factor is *u*/MAX not *u*/MAX0. But David Ross says that "to adjust *xu*/MAX0 to make it equal *xu*/MAX, just add one whenever *xu*/(MAX0**MAX) is greater than 0.5, *i.e.* when 2*xu* exceeds MAX0**MAX."

All these binary manipulations make it impractical to present the revised rand0( ) and randi( ) in any language but assembly language. Versions for the 8086 and Z80 follow. If we had versions for the 6xxxx machines, we'd print 'em and will if you send us some.

Considering QRNGs

The strongest impression we've gained from this exercise in QRNGs is of our own ignorance. A *lot* is known about the design of QRNGs, and most of it is strongly mathematical. The best source we know is Donald Knuth's *Seminumerical Algorithms*, pages 1–178. There oughta be a law that nobody can write about QRNGs until they pass a midterm on this material—in which case, this column would be on another topic even though we spent several hours recently poring over that chapter.

We learned quite a bit about linear congruential QRNGs, but the Talley-Metropolis routine is not one of those. Mathematically, it can be stated as:

$$X_n = ((X_{n-1} + X_{n-2}) \bmod \text{MAX0}) * 2) \bmod \text{MAX}$$

which is not identical to any of the QRNG formulae Knuth treats (although it bears an uncomfortable resemblance to the Fibonacci sequence, whose output Knuth says "is definitely *not* random").

We also learned that you should *never* base an application on a QRNG that hasn't been formally justified and thoroughly tested. Therefore you shouldn't rely on this one. We publish it because readers might enjoy working *on* it, as opposed to *with* it.

We also learned a lot about testing QRNGs; Knuth is particularly good on that subject. In particular, we

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know that you can spend about as much time as you like coding, running, and analyzing tests. The time we could spend on this project was severely limited. But here are what we and our correspondents have learned.

Period Length

A major point of interest is the length of the sequence of numbers the QRNG will produce. Michael Barr's approach to this was interesting and could be the basis of more extensive theoretical and practical work. "You can think of it as tracing an orbit among the sets of pairs of numbers (a,b) with a and b in the range 0 . . . MAX. And you can ask the question, what is the length and nature of that orbit?

"Clearly, (0,0) is an orbit of its own. In particular, the generator can never produce two zeroes in a row [*really? DEC*]. This is, by itself, a failure of randomness, perhaps not a serious one, but nonetheless a failure.

"When I tried it with MAX0 = 8, I discovered that the other 63 pairs were all in one orbit! This was surprising, but when I tried out other values of MAX0 (all even) I found that this is a fluke. For no other small value of MAX0 do all the nonzero pairs make up a single orbit. For example, for MAX0 = 6, there is an orbit of length 14, one of 16, and two of length 1—(0,0) as always and (4,4). As a matter of fact, if MAX0 is divisible by 6, there is always that second fixed point."

We'd been operating under the assumption that a generator that produced 16-bit numbers would have a maximum period of 65,536, but that proved not to be the case. We hacked together a version of what Knuth calls the collision test. This program cleared 64K bits (8K bytes) then called Rand0 256 times and set the selected bits to one. Then it began getting and counting Rand0 values and testing the bits they indexed. It counted successive hits of 1-bits.

We had presumed that, if the QRNG were working right, it would generate 64K numbers and then start repeating, hitting all 256 1-bits in a row; or it might hit them all again sooner, indicating a short sequence from the original seeds; or it might get into a loop hitting 0-bits and never return to the original 256 numbers.

Nothing of the sort happened. It behaved instead like a well-distributed generator with a much, much longer period. It made single hits at intervals of roughly 256 probes; it made double hits at intervals of roughly 64K; and when we stopped after 1.5 million probes, it had yet to hit three 1-bits in a row (intuitively, that should happen around 24 million), nor had it looped.

This is an intriguing result. A QRNG with such a long period that codes so tightly in a 16-bit machine is a rare bird. We only wish that somebody would analyze its period from a theoretical standpoint. It would be almost as nice if somebody would carry out a longer collision test.

A question related to period length is: What is a good initial seed? The QRNG is initialized with two numbers; what should they be for a maximal period? It's all very well to stick in two 16-bit prime numbers; if we had any theoretical understanding, we might be able to specify rules for the selection of good seeds.

Distribution

Of equal concern is the distribution. A few short tests have been made. Everett Carter generated 1000 numbers using randi(100) with the flawed randi( ) function. He subjected them to a Chi-squared test with 99 degrees of freedom; the result was a probability of 0.82 that the sample was drawn

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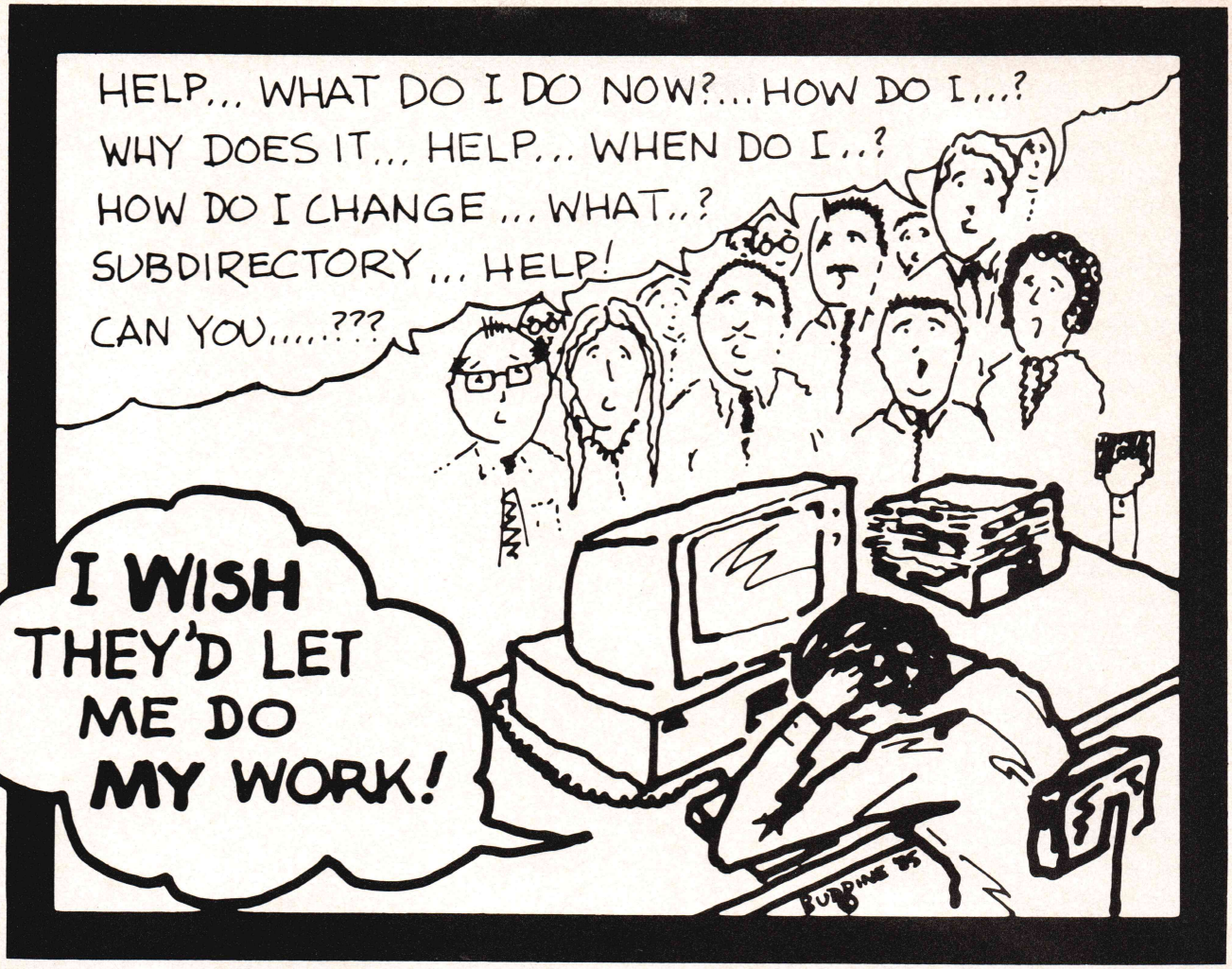

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from a uniform distribution. Says Carter, "if I needed a uniform distribution, I'd try for better than 0.82."

Barr notes that, "provided MAX0 is even, it is possible to run the generator backwards. That is, if you think of it as producing a sequence X_1, X_2, ... X_n, you can calculate X_{n-2} from X_n and X_{n-1}."

Peter Pearson made the remarkable assertion that "sets of numbers drawn three at a time from rand0 are strongly interdependent. Specifically, if p, q, and r are the results of three successive calls on rand0, the quantity $2(p+q)-r$ can have one of only four values: 0, 32767, 65536, and 98303."

But on the other hand, Carter said, "On the correlation test, this generator does very well over short spans (I never tried long spans). This test measures the independence of the numbers by calculating the correlation between one number and a number later in the series. In the tests that I made with a lag distance of up to 20 intervals, the correlations are below 0.1 and most are well under 0.05. While one might hope for more independence, these values are very good relatively."

Clearly many more tests of this QRNG should be done. Knuth recommends the runs test and the collision test as particularly powerful and describes algorithms for them and several others.

The Mitchell-Moore QRNG

There is another simple QRNG, one that has guaranteed good characteristics and a ridiculously long period. Its only drawback is that it needs 55 words of auxiliary space and a second QRNG to seed it. Knuth credits the method to J. G. Mitchell and D. P. Moore; its formula is:

$$X_n = (X_{n-24} + X_{n-55}) \bmod \text{MAX0}$$

It is easily expressed in C; see Listing Four (page 27). It uses a 55-integer array initialized with numbers not all of which are even; usually these 55 seeds are drawn from a simpler QRNG (Talley-Metropolis will do). The constants 24 and 55 are not arbitrary; they were chosen because they produce a period of length 2^{55}. Nor

Dr. Dobb's Clinic (Text begins on page 20)

Listing One

```
rem recurse.bat called with %1 %2 %3 %4 %5 %6 %7 %8 %9
if (%1)==() exit
prompt command level %1$g
command /c recurse %2 %3 %4 %5 %6 %7 %8 %9
```

End Listing One

Listing Two

```
; Talley/Metropolis routines for 8086.  Consumer Warning: This
; generator is experimental and lacks a sound mathematical
; basis or statistical validation -- USE AT YOUR OWN RISK.
;
; Rand0: return a 16-bit quasi-random number in AX.
;       Preserves all registers except AX, flags.
Rand0:
        push    dx
        mov     dx,Xminus2
        mov     ax,Xminus1
        mov     Xminus2,ax
        add     ax,dx
        rol     ax,1
        mov     Xminus1,ax
        pop     dx
        ret
;
; RandI: return in AX a number in 0..CX-1.
;       Preserves all except AX, flags.
RandI:
        push    dx
        call    Rand0   ; ax = rand0()
        mul     cx      ; dxax = u*rand0()
        mov     ax,dx   ; ax = u*rand0()/MAX0
        pop     dx
        test    ah,80h
        jz      RandIx
        inc     ax      ; ax = u*rand0()/MAX
RandIx: ret
```

End Listing Two

Listing Three

```
; Talley/Metropolis routines for Z80.  Consumer Warning: This
; generator is experimental and lacks a sound mathematical
; basis or statistical validation -- USE AT YOUR OWN RISK.
;
; Rand0: return a 16-bit quasi-random number in HL.
;       Preserves all except HL, flags.
Rand0:
        push    de
        ld      de,(Xminus2)
        ld      hl,(Xminus1)
        ld      (Xminus2),hl
        add     hl,de
        add     hl,hl
        jr      nc,Rand0q
        inc     hl
Rand0q: ld      (Xminus1),hl
        pop     de
        ret
;
; RandI: return in HL a number in 0..BC-1.
;       Preserves all except HL, flags.
```

(Continued on page 26)

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are they unique; Knuth gives a table of other good pairs. Use 27 and 98 if you think you need a period of 2^{98}.

Random 8086

The routines in 8086 assembly language may be found in Listing Two (page 24). The seeding routine is omitted, as are details of segment definitions. Pay close attention to the consumer warning in the comments. It was Michael Barr who spotted the elegant equivalence between the C statements

```
c *= 2; if (c>MAX) c -= MAX;
```

and the single 8086 instruction

```
rol ax,1
```

Boy, if you ever see a C optimizer that can find that transformation, buy it.

Random Z80

The QRNG in Z80 assembly language is in Listing Three (page 24). The most complicated part of the Z80 (or any other 8-bit) version is the simulation of a 16-bit unsigned multiply. The one in Listing Three is a standard routine straight out of that classic work, *Z80 Programming for Logic Design* by Osborne, Kane, Rector, and Jacobson, published in the distant year of 1978 by Osborne and Associates and still one of our most useful references.

The only change we've made in Osborne's multiply is to use long jumps (JP opcodes) instead of short relative ones. A JP takes 10 clock cycles to do regardless, while a JR takes either 7 ticks to fall through or 12 to jump. Ordinarily, a JR is the opcode of choice because it is a byte shorter and, under the assumption that it will fall through and be taken with equal frequency, should consume half a clock cycle less on average.

However, if we can predict anything about the frequency with which a branch will be taken, we should make a choice between jump types. The last JP in Listing Three, for instance, will be taken 15 times and fall through but once. Clearly it ought to be a JP, since a JR would cost 30 more cycles.

The first of the three jumps should be a JR. It tests successive bits of the multiplier. In this application, those are bits of a quasi-random number, and the 50-50 assumption certainly ought to hold, indicating the use of JR. In a general-purpose multiply routine, we might expect that both multiplier and multiplicand will be positive binary numbers, but even if we expect only positive numbers less than 2^{15}—so that we expect the jump to be taken 9 of 16 times (i.e., always taken for the first two bits and taken for half of the other 14 bits)—the JR still squeaks out two-tenths of a clock cycle faster than a JP.

The middle jump is not so obvious, but because it will be executed in any manner on half or fewer of the iterations, it is also less important. In effect, we choose here between a 5-cycle JP or a 3.5/6 cycle JR. The jump will be taken when no carry results from adding the multiplier into the low word of the partial product. At first we thought that would be 3 out of 4 times, a clear win for JP over JR; on reflection, we ain't so sure. What do you think?

DDJ

(Listings begin on page 24)

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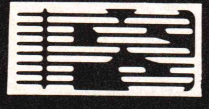

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Dr. Dobb's Clinic (Listing continued, text begins on page 20)

Listing Three

```
;       Requires Mul16 to do DEHL = BC*HL
RandI:
        call    Rand0   ; HL = rand0()
        push    de
        call    Mul16   ; DEHL = BC*rand0()
        ex      de,hl   ; HL = BC*rand0()/MAX0
        pop     de
        bit     0,h
        ret     z
        inc     hl      ; adjust to .../MAX
        ret

; a usable 16-to-32-bit multiply subroutine, producing
; DEHL as the 32-bit result of HL * BC, preserves BC, AF.
Mul16:
        push    af
        ld      a,16    ; loop count
        ex      de,hl   ; multiplier to DE
        ld      hl,0    ; clear partial product
Mul16A:
        ex      de,hl   ; next multiplier bit
        add     hl,hl   ; ..shifted to carry
        ex      de,hl   ; ..and 0-bit appended to hi prod
        push    af      ; (save m'ier bit)
        add     hl,hl   ; next product bit to carry
        jr      nc,Mul16B
        inc     de      ; adjust bit shifted earlier
Mul16B: pop     af      ; if m'ier bit was 1,
        jr      nc,Mul16C
        add     hl,bc   ; add multiplicand to product
        jp      nc,Mul16C
        inc     de      ; ..propogating carry
Mul16C: dec     a
        jp      nz,Mul16A
        pop     af
        ret
```

End Listing Three

Listing Four

```
/* Mitchell-Moore QRNG in C.  Presumes the existence of a */
/* simpler QRNG named r0rand() and its seeder, r0seed(x). */

extern void r0seed();
extern unsigned r0rand();

static unsigned xa[55];
static int j,k;

rseed(x)
unsigned x;
{
     r0seed(x); /* initialize rand0() predictably */
     for(j = 0; j < 55; ++j) xa[j] = r0rand();
     j = 23;
     k = 54;
}

rand()
{
unsigned x;
     x = xa[k] += xa[j];
     if (j==0) j = 55; --j;
     if (k==0) k = 55; --k;
     return(x);
}
```

End Listings

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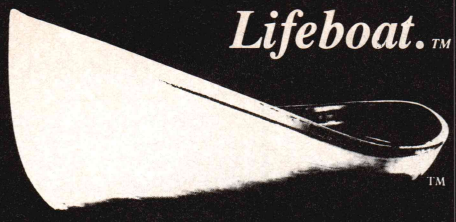

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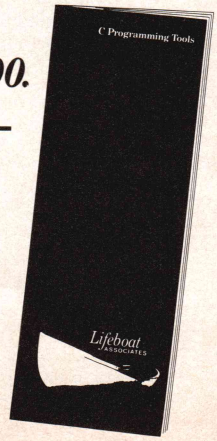

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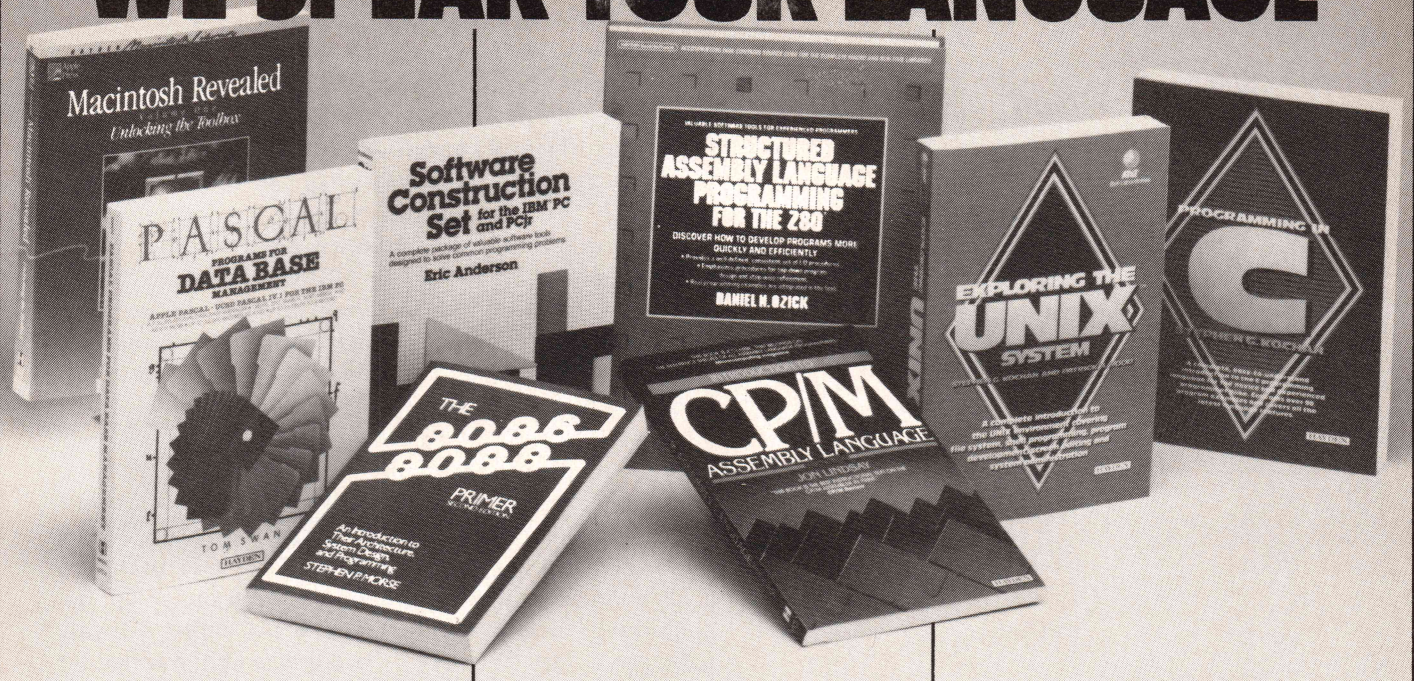

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C Compilers for MSDOS

by the C Special Interest Group
of PicoNet and the Silicon Valley
Computer Society under the
direction of Richard Relph

Our reviewers found that some of the fastest compilers overall were relatively slow in doing screen I/O, and uncovered order-of-magnitude differences in execution time and generated-code size.

What would you consider the ideal credentials for a reviewer of computer language compilers? Would you want a software designer, or perhaps even a compiler designer? Should the reviewer be a professional who earns his or her living at the keyboard? Or should the review be conducted by the weekend programmer who really understands the value of user-friendly software as well as the frustration of user-hostile documentation?

The reviewer for this project is all of the above. This report on 13 C compilers for MSDOS was conducted by the joint C Special Interest Group (C-SIG) of PicoNet (a non-profit, general microcomputer users' group) and the Silicon Valley Computer Society (SVCS), an IBM PC users' group.

This combined C-SIG is composed of a broad cross-section of microcomputer users. Some are language-compiler designers, some design and maintain systems software, still others make their living developing commercial software such as spreadsheet or data base packages. There are several novice programmers in the group, but most are seasoned programmers, if not expert software designers. The "reviewer," therefore, is well qualified for the job.

Background

The first C-SIG was organized in 1983 by a group of PicoNet members. Their purpose was to provide a forum for discussion and study for those interested in the C programming language. In the beginning, classes were organized, and after 10 or 12 sessions the language was covered fairly thoroughly. The classes brought all members of the group to a common basic level of understanding of C.

The group soon graduated to developing software utilities: those tools that are commonly found on the larger systems for which C was originally developed, but that are not commonly available for the microcomputer environment. The C-SIG also organized group purchases of compilers, other software packages, and hardware at discounts, so that all members could own a quality C compiler, participate in the various group activities, and contribute to group projects.

Invariably, at the monthly meetings someone would ask what was the best current compiler (or version thereof), opening a debate over which compilers were the fastest, which produced the optimum code, which conformed most to "standard" C. We soon recognized from these discussions that the group was somewhat inbred; that is, among the 20 or 30 members, only two or three C compilers were represented (partly due to group purchases). Then, near the beginning of 1985, the PicoNet and SVCS C-SIGs merged.

SVCS was made up of IBM PC users. PicoNet was traditionally a CP/M group, but a large number of the original C-SIG members had recently acquired MSDOS-based PCs through a group purchase. Out of the group's new interest in MSDOS came increased interest in C compilers that ran under MSDOS. We soon discovered that the number of compilers available for the PC environment

was large indeed, and we quickly identified some 24 implementations. The questions of which was fastest, which produced the tightest code, and which was closest to the standard continued to come up, but we learned that no one had the answers. We decided to find them.

Given the magnitude of the task, the breadth of the group, and the number of individuals involved in the project, responsibilities had to be divided among the participating members. Each joined a group that was assigned a specific task critical to the overall project. The groups had responsibilities in the following areas:

- Standards: responsible for the evaluation of compilers' and libraries' adherence to the standard C language as defined by Kernighan & Ritchie (K&R) in *The C Programming Language*. Also responsible for qualifying all benchmarks written or acquired to measure compiler performance for universal compatibility and for assessing each compiler's ease of use (Richard Relph, Don Lawrence, Andi Pisiali, Stan Peters).
- Benchmarks: responsible for writing and/or acquiring C compiler benchmark programs and for conducting benchmark tests (Fred Viles, Steve Mahn, Scott Thomas, George Giomousis, Bill Overstreet, Fletcher Johnson).
- Documentation: responsible for reviewing documentation for clarity, completeness, style, and presentation. Also responsible for evaluating customer service for responsiveness and technical proficiency (Chuck Rulofson, Don Hockler, Bob Stephan, Peter Vutz).
- Writers: to put it all together (Irwin Diehl, Don Dodge).

That's the background—who we are, what we did, why we did it, and how. Oh yes, we should mention the "where." We've been most fortunate to have been provided a regular meeting place by ZeroOne Systems (formerly Technology Development of California). ZeroOne has been a most gracious host for the regular monthly meetings and the special weekend benchmark sessions. Their continuing support is appreciated.

Benchmarks

The benchmark group was charged with measuring the performance of the code produced by the various compilers. In the course of several meetings, we decided on our general approach and on the specific benchmark functions to be produced. We first discussed the possibility of producing a real-world benchmark program, one that would perform some useful function using an appropriate mix of language and library features. This plan, although attractive, was problematic since we could not agree on an appropriate mix. We settled on a "surgical" approach: many small functions, each intended to test a single feature of the compiler or its library.

We started by drawing up a list of every aspect of compiler and library performance that any one of us had ever wanted to see in other compiler reviews; not surprisingly, the list was enormous and impossible. In the interest of completing this project at all, we pared the list down, ending with 30 separate benchmarks to test performance

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Efficient C (Thomas Plum and Jim Brodie, 1985) provides a small suite of C functions into which the reader can "plug in" any C statement and determine how many microseconds of CPU time it takes to execute. Expanding upon this technique, the book presents tables of CPU time and code space for C operators, control structures, and function calls. These allow the reader to make fairly accurate estimates of the resources that a program will take, without resorting to assembler listings. The book discusses optimization techniques performed automatically by several compilers, as well as those techniques which can be effectively used by the programmer. (Plum and Brodie are respectively Vice-Chair and Chair of the ANSI committee X3J11 which is standardizing C language.)

Reliable Data Structures in C (Thomas Plum, 1985) is an intermediate-level book that picks up where introductory books leave off. It describes techniques for a "no surprises" usage of pointers, structures, and files. Standard data structure techniques like stacks, queues, and trees are presented using reliability techniques, along with a complete menu-and-forms screen generator. Relevant information about the draft ANSI standard for C is presented to allow programmers to write compatibly with existing and forthcoming compiler and interpreter environments.

Learning to Program in C (Thomas Plum, 1983) presents the fundamentals of C. Presupposing only an acquaintance with computers, it covers C up through the basics of pointers and structures.

C Programming Guidelines (Thomas Plum, 1984) provides a style standard for projects working in C language. Arranged in "manual-page" reference format, it gives rules for using variables, data types, operators, expressions, statements, functions, files, libraries, and documentation.

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in the areas of code size; time to compile and link; storage class support; math; array and pointer referencing; function calling; optimization; screen and disk I/O; and general performance. We ran some of these functions for different memory models and some with the 8087 options available.

To get accurate and consistent results, we used a common format for all the execution-time benchmarks. Each benchmark was written as a function that accepted a loop count and returned the measured time in tenths of seconds. We wrote a pair of functions to measure an interval of time using the system clock, avoiding the problems inherent in the stopwatch approach. All compilers except Digital Research's provided a library function giving access to DOS interrupts, so the timer functions could be written easily in C for all but DRI. (So we wrote an assembly routine.) We then verified that the overhead in the timer functions was negligible for all compilers. The skeleton for all benchmark functions is in the Figure (below).

We adjusted each loop count to force the benchmark into a reasonable time frame (about 1 minute), so as to minimize the percent error in the timer functions. Although the system-clock interrupt returns a measurement of the time down to hundredths of a second, the clock is actually updated only 18 times per second, so the time reported for a given function can vary by as much as 0.2 seconds.

Except for the 8087 benchmarks, all the tests were performed on a Leading Edge PC. running MSDOS 2.11 and equipped with 640K RAM and a 10 Mb hard disk. These machines are close PC-compatibles running at a clock rate of 7.16 MHz; consequently, CPU-bound benchmarks will take 50 percent longer on an IBM PC. The Norton Utilities (V3) confirm this performance factor.

We selected the Leading Edge PC because we had made a group buy of several identically configured systems. We ran the compile-time and link-time benchmarks on the same machine in two different ways: using the hard disk, with care taken to ensure that files were read and written to the same location for each compiler, and on a 512K JDrive RAM disk. We ran the disk I/O benchmarks on the hard disk, again ensuring that the same disk locations were used. Before you moan "but I only have a plain IBM PC with floppies," remember that the goal here was to compare the compilers, not the machines. The ratio of the timings should be the same anywhere.

```
benchfn(loop)
int loop;
{
    /* Initialization */

    time_0( ); /* Start clock */
    for ( ; loop ; loop-- )
    {
        /* Code to be timed */
    }
    return(time_n( )); /* As sec/10 */
}
```

Figure

Benchmark Design

So much for background. Now we will discuss the benchmark functions, grouped by aspect to be tested. We have listings for all but the compile- and link-time programs, which were not actually executed. For a diskette (5¼-inch MSDOS) with the listings send a check for $6.00 payable to M&T Publishing to: *DDJ* Compiler Review, 2464 Embarcadero Way, Palo Alto, CA 94303.

Code Size

We wanted to get an idea of the granularity of the library and the minimum .EXE file size that could be produced. Granularity, for those not familiar with the term, refers to how finely the library is structured. A highly granular library allows the bare minimum of object code to be linked for each function. Four programs were written for these tests:

- minmain.c—Main program with no executable code.
- minputs.c—Main program with one puts( ) call.
- minprtf.c—Main program with one printf( ) call.
- minfio.c—Main program with calls on fopen( ), fgets( ), fputs( ), and fclose( ).

We compiled and linked, but did not execute, each program. We were especially interested in minprtf.c, since using printf( ) usually means dragging in the whole floating-point package. Some compilers provided an option to link with an integer-only version of printf( ). In those cases we linked minprtf.c twice, once with the integer-only and once for the full floating-point versions of printf( ). See Table 1 (page 34) for the results.

Clocking Compile and Link Time

Since most of the performance benchmarks are very short and not representative of typical programs, we used separate programs ranging from 1 to 1000 lines for this test. They were:

- doc1.c—A one-liner, to show the minimum overhead.
- doc10.c—A 10-liner, about the smallest module you'd ever compile.
- doc100.c—This 100-liner is the most significant since it represents a typical size of source file.
- doc1000.c—A 1000-line program. Basic overhead should be minimal here.

Doc100.c was produced from a preexisting program belonging to one of the group. Doc1000.c is a stripped-down version of the DIFF program available from DECUS (Digital Equipment Corp. Users' Society).

Since modular compilation tends to be the rule with C programming, we timed the compile and link steps separately. The compile step included all phases of the compila-

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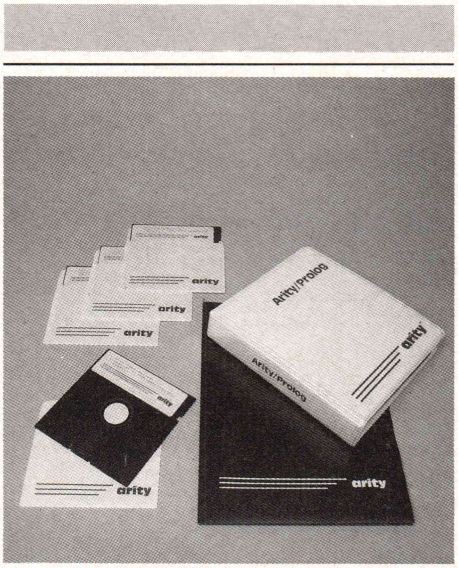

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Table 1
.EXE File Size

Vendor	DOC1		DOC10		DOC100		DOC1000	
	compile	link	compile	link	compile	link	compile	link
Aztec (Manx)	**2**	**2**	3.5	**3**	16.5	**4**	103	**5.5**
Control C	2	12	**3**	12	12	19	69	21
C Systems	6	11	9	14	39.5	17.5	233	19
Computer Innovations	6	10	7	14	19	16	105	20
Datalight	2.5	3	3	5.5	12	9	NA	NA
DeSmet	3	3.5	**3**	4	**6**	**4.5**	**28**	**5**
Digital Research	3	16	4	20	17	25	120	29
EcoSoft	3	3	4	13	13	18.5	NA	NA
Lattice	2.5	9.5	4	10	18.5	11.5	126	15.5
Mark Williams	**2**	12	**3**	12	12	19	69	21
Microsoft	4	3	6	5.5	20	7	131.5	9.5
Software Toolworks	3	11	6	13	28	15	243.5	20
Wizard	3	**2**	**3**	7	10	9	54	12.5

Table 2a
Compile and Link Times: RAM Compilation

Vendor	DOC1		DOC10		DOC100		DOC1000	
	compile	link	compile	link	compile	link	compile	link
Aztec (Manx)	**8**	**5.6**	9.5	**8**	24.5	**10**	116	**12**
Control C	13	20	14	20	26.5	27.5	93	30
C Systems	17	18	20	22	52	25	255	27
Computer Innovations	21.5	15	22	20	37	23	128	28
Datalight	8.5	7	**9**	11.5	20.5	15	NA	NA
DeSmet	10	7	10	8.5	**14.5**	**10**	**43**	**11**
Digital Research	13	24	14	29	28	36	135	40
EcoSoft	14	7	15	20.5	27	26	NA	NA
Lattice	9	15.5	10	16	27.5	18	149	22.5
Mark Williams	13	20	14	20	26.5	27.5	93	30
Microsoft	19	8	21.5	13	38	15	159.5	20
Software Toolworks	9	18	11.5	21	35	24	254	30
Wizard	15	5.5	17	13	27	16	78	20

Table 2b
Compiler and Link Times: Hard-disk Compilation

Vendor	Overall performance and misc.						
	looptst	optim	fibtest	sieve	rsieve	psieve	isort
Aztec (Manx)	**37.8**	35.7	56.2	**99.0**	58.0	53.3	42.0
Control C	62.2	40.9	63.0	103.4	59.1	54.8	60.0
C Systems	100.8	73.1	69.7	173.8	132.6	190.7	51.5
Computer Innovations	66.1	39.8	54.0	117.5	117.4	119.3	49.0
Datalight	63.0	35.3	**49.8**	**99.9**	100.0	101.3	**42.6**
DeSmet	63.0	46.4	52.9	108.2	108.4	103.4	53.8
Digital Research	58.8	66.9	51.7	104.8	58.8	57.0	49.9
EcoSoft	63.0	50.7	52.0	115.3	115.4	138.1	85.7
Lattice	63.0	**25.0**	70.0	100.3	100.2	96.9	77.2
Mark Williams	61.8	40.8	63.0	103.3	59.0	54.7	59.7
Microsoft	58.8	59.0	59.0	99.4	**54.9**	**50.0**	44.3
Software Toolworks	74.2	31.8	56.4	133.6	110.3	176.8	123.6
Wizard	58.8	68.8	52.6	101.0	55.7	51.1	60.0

Table 3a
Execution Times

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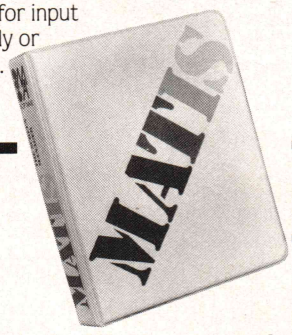

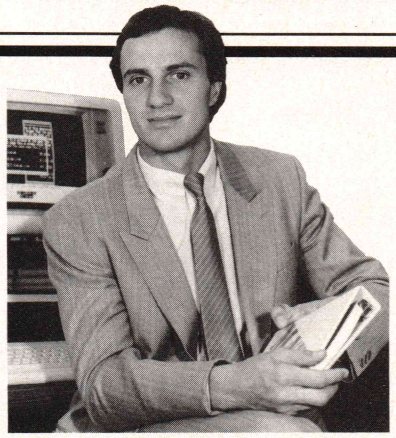

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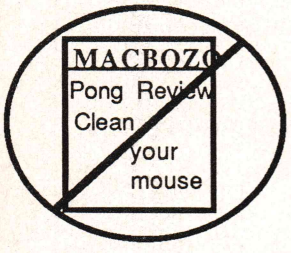
tion, including assembly, if any. The compile and link process was controlled by a batch file since we weren't interested in benchmarking the testers' typing speeds. Some compilers provided a control program that allowed the linker to be run automatically after the compile with a single command. In these compilers, we defeated that option and issued a second command to do the link so we could derive separate compile and link times. To produce the time estimate, we used the Norton Utilities timemark program, invoking it from the batch file at the appropriate points. See Tables 2a and 2b (page 34) for these results.

Testing Screen and Disk I/O

We wanted to test how fast the generated code could write to the console using puts( ) and printf( ), as well as how fast it could read and write to the disk. We wrote six functions to find out.

- The fillscr.c function used puts( ) to write a string of 1248 characters to the screen without scrolling. Scrolling was prevented by using a bare carriage return every 78th character of the string. The screen gradually fills because puts( ) adds its own newline at the end of the string, and the puts( ) call is repeated <loop> times. The screen was cleared by the DOS CLS command prior to running this test.
- The scroll.c function was almost the same as fillscr( ), except the string had a newline every 78th character so each puts( ) produced 16 lines of characters plus a blank line on the screen. So the time difference between scroll( ) and fillscr( ) measured the scrolling overhead.
- The prtf.c function produced the same number of characters and lines as scroll( ), except it used printf( ) instead of puts( ) and executed each basic format conversion several times. Comparing the time for prtf( ) to that for scroll( ) shows how efficiently the compiler's printf( ) function performs its conversion duties.
- The cpychr.c function copied a 10,000-byte file using fgetc( ) and fputc( ).
- The cpyblk.c function copied a 10,000-byte file using fread( ) and fwrite( ) to copy in 1024-byte blocks. The difference between the times for these functions reveals the advantage blocked I/O has in a particular compiler's library.
- The diskio.c function was designed to test random character I/O to a reasonably large data file. It used fseek( ), fgetc( ), and fputc( ) to randomly read and write individual characters in a previously created data file 240,000 bytes long.

We argued about whether to use fopen( ), fread( ), fwrite( ), and the like, rather than open( ), read( ), write( ), and other corresponding functions. The latter functions were provided with many of the compilers and might have produced faster times, but ultimately we decided to use the f functions, primarily on portability con-



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siderations. The February 1985 preliminary draft of the proposed ANSI standard does not include open( ), et al., on the grounds that they are too closely tied to the Unix operating system and that they are redundant. We dodged the potentially sticky problem of conversion between newline and CR-LF by making sure that none of the data files contained these characters.

Testing String Library Functions

We wanted to test some library functions beyond the usual I/O functions. We were concerned, though, that many of the functions we could test would not be provided with all of the compilers, so we wound up with a single benchmark function, isort.c, to test strcmp( ) and strcpy( ). This function used strcmp( ) and strcpy( ) to perform a simple sort of an array of up to 1024 eight-character strings. (In this case, the <loop> parameter was used to control the number of elements to sort; it does not represent the number of sorts performed.) The isort.c test tells little about compiler performance per se, but it does give a clue as to how well the runtime library was written.

Math Tests

We wrote four functions to test basic arithmetic functions for various data types.

- The tint.c function includes 1500 add, 1600 subtract, 200 multiply, and 200 divide operations, <loop> times. Inner loop overhead amounts to <loop> * 100 test-for-zero and decrement operations. Since there are not many ways to perform 16-bit integer arithmetic on an 8088, we expected most of the compilers to perform about equally on this one.
- The tlong.c function was exactly the same as tint( ), except that the variables involved in the adds, subtracts, multiplies, and divides were all declared long instead of int. Significant differences between compilers were more likely here.
- The tfloat.c function tested floating-point arithmetic with 40 each adds, subtracts, and multiplies and 20 divides, all done <loop> times.
- The tdouble.c function was the same, except that the variables were declared double instead of float. For most compilers, tdouble( ) should be somewhat faster than tfloat( ) since K&R calls for all floats to be converted to double before being used in an expression. Tfloat( ) and tdouble( ) were run with whatever flavors of floating-point support (including 8087 options) were available for each compiler. The results of these tests appear in Table 3b (page 38) and Table 4 (page 43).

Array and Pointer Tests

We wrote two functions to explore how efficiently the compilers handled array- and pointer-referencing tasks.

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The function array.c simply initialized a three-dimensional array of 1000 ints, and pointer.c did the same, but using a pointer to a pointer to a pointer to an int. The unnecessary extra levels of indirection were added to increase the amount of pointer dereferencing relative to the overhead; i.e., to increase the ratio of data to noise.

Function Call Tests

To test the overhead due to function call and return, we created a version (fibtest.c) of the fib benchmark from the August 1983 issue of *Byte* magazine. (This is a good test of function-call overhead because it's composed entirely of negligible arithmetic and recursive calls.) As with tint( ), the optimum code for function calls and returns is well known, so we did not expect to see much variation between compilers on this test, although significant differences would be interesting.

Storage Class Tests

We were curious about the efficiency of the code generated for variables of various storage classes and in particular about how well register variables were supported. To find out, we wrote three almost-identical functions: autotst.c, stattst.c, and regtest.c. Each contained four empty **for** loops. The only difference among the functions is that the four loop variables were declared with automatic, static, and register storage classes, respectively.

Looking For Optimization

We thought it would be a nice idea to try to determine just how extensive each compiler's optimization algorithms were. To that end we wrote optimize.c, a mishmash of statements that a compiler could reasonably be expected to optimize. The idea was that the more cases a compiler noticed and optimized, the better its performance on the test would be.

Assessing General Performance

The looptst.c function did nothing at all; it was just an empty loop. We included it so that we could get an idea of how much overhead was being introduced by our outer loop in each of the benchmarks. Looptst( )'s inner loop did nothing 10,000 times, so there were 5,000,000 total loop iterations.

We knew we could not get away with not running the infamous *Byte* sieve benchmark, so we decided to go overboard and produce three, starting with sieve.c, our version of the standard sieve benchmark as published in the January 1983 *Byte*. We added rsieve.c, identical to sieve( ) except that the two most frequently referenced variables were declared register. This is the way some vendors run the sieve when producing numbers for their advertising copy. And we wrote psieve.c, a pointerized version of the sieve. This function may not prove very useful in comparing compilers, but writing it was an interesting exercise. It showed us that it is not true that using pointers is always better than using array references. Psieve( ) is considerably less readable and performs only marginally better than rsieve( )—on some compilers it actually ran at a slower rate!

Vendor:	Math functions:				Array/ptr:
	tint	tlong	array	ptr	
Aztec (Manx)	**34.0**	125.4	**30.7**	**50.4**	
Control C	36.4	176.1	96.4	72.5	
C Systems	39.3	247.9	90.0	85.0	
Computer Innovations	36.9	215.8	95.1	71.9	
Datalight	35.4	**87.7**	61.4	65.2	
DeSmet	36.0	178.9	93.6	68.0	
Digital Research	**34.1**	808.4	96.8	68.0	
EcoSoft	36.0	298.8	91.7	68.0	
Lattice	36.3	192.8	60.2	66.8	
Mark Williams	36.7	175.4	96.4	72.5	
Microsoft	**33.5**	102.9	76.2	**50.4**	
Software Toolworks	59.0	N.A.	131.5	116.8	
Wizard	**34.0**	173.0	78.4	**50.4**	

Vendor:	Screen I/O:		Disk I/O:				Storage class support:		
	fillscr	scroll	prtf	cpyblk	cpychr	diskio	autost	stattst	regtst
Aztec (Manx)	50.5	57.8	61.7	98.2	**39.7**	62.8	**70.6**	**79.3**	**54.2**
Control C	**22.3**	**29.0**	37.6	104.2	59.5	47.6	72.3	81.1	**54.1**
C Systems	31.0	35.5	42.1	182.6	82.2	**26.7**	126.9	136.0	108.8
Computer Innovations	27.8	32.6	58.1	147.0	**42.0**	50.9	79.3	86.6	79.3
Datalight	49.9	54.7	63.9	123.6	53.3	N.A.	79.4	86.5	79.4
DeSmet	27.8	31.5	48.1	128.8	94.6	48.1	79.4	86.5	79.4
Digital Research	37.5	41.9	**35.9**	176.0	83.3	36.2	**70.5**	**79.3**	**52.2**
EcoSoft	31.3	37.8	40.8	N.A.	N.A.	N.A.	79.4	86.5	79.4
Lattice	62.4	67.5	71.0	129.0	63.5	66.1	79.3	86.5	79.4
Mark Williams	**22.3**	**29.0**	37.5	156.1	85.0	42.4	72.2	81.1	**54.0**
Microsoft	47.7	55.0	59.1	**73.0**	53.0	57.0	**70.5**	**79.3**	**52.2**
Software Toolworks	62.5	67.6	67.9	726.0	334.2	55.3	112.6	136.0	112.5
Wizard	49.7	54.7	65.5	139.7	60.4	55.5	**70.6**	**79.3**	**52.3**

Table 3b
Execution Times continued

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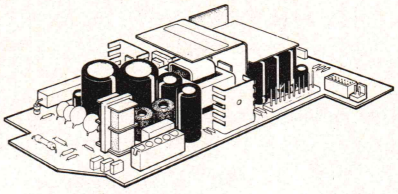

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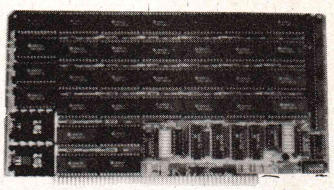

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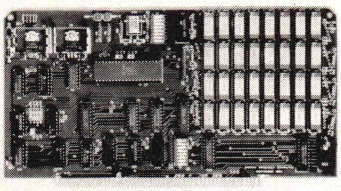

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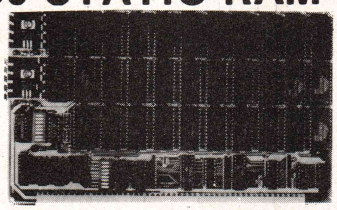

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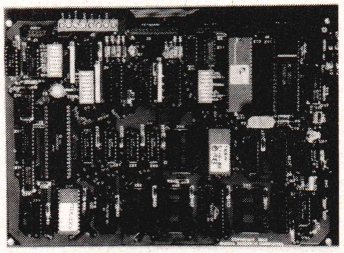

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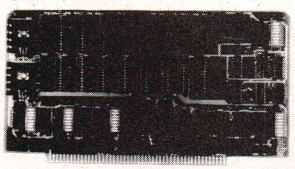

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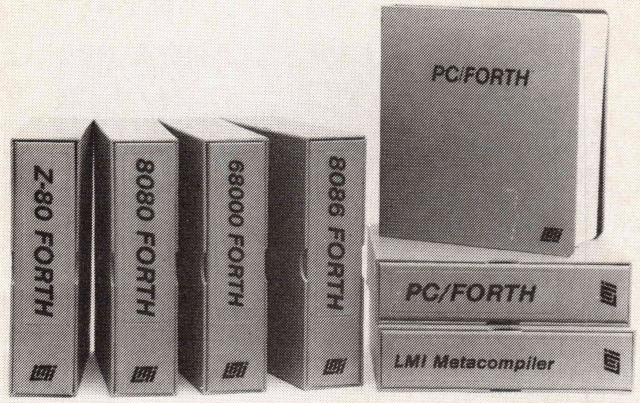

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Testing Memory Models

All the benchmarks mentioned were compiled and run under the small-memory model. To see what kind of performance penalty you pay to use other models, we compiled and ran array( ), pointer( ), and psieve( ) with every other memory model option available with each compiler. In retrospect, we probably should have included fibtest( ) and maybe sieve( ) in the set.

Benchmark Results

You can see the results for all these benchmarks in Table 3a (page 34) and Table 3b (page 38). Since there are some surprises and discoveries that may not jump out at you from all those numbers, we want to discuss some of the more interesting (in some cases, bizarre) results. We'll discuss them by functional grouping.

In the area of screen I/O, none of the compilers was so fast as to indicate that the library routines were writing directly to screen memory (which could be a portability problem), but there was a wide range in performance. The compilers seemed to separate into two groups. Mark Williams' compiler was the fastest in a group clustered around 30 seconds, with MicroSoft's the fastest in a group clustered around 55 seconds. This suggests the use of two divergent methods of handling screen I/O under MSDOS.

Also, we were surprised to find that for most compilers, prtf( ) was not much slower than scroll( ). We had expected the conversion overhead to be significant, but this was true only with Computer Innovations' compiler and, to a lesser extent, with DeSmet's. A real anomaly was Digital Research's compiler, whose prtf( ) time was faster than scroll( ) and even faster then fillscr( )! That means that in DRI's compiler there is some overhead associated with using puts( ) that is avoided in using printf( ); this made no sense to us.

The storage class tests basically tested the efficiency of loading data from memory. Since there are only a limited number of ways to load a two-byte quantity from memory, it is not surprising that there were many-way ties in this category. In fact, except for the two slowest compilers (c-systems' and Software Toolworks'), all the compilers were closely ranked for all three tests. There were four compilers tied for first, followed by two more just a couple of seconds slower and five more tied a bit further off. Mark Williams' and Control C's compilers were the two tied in the second group, but that's no surprise; they tied in every test. They are really the same compiler.

If we compare the regtest( ) and autotst( ) results, it becomes clear that all the faster compilers implemented register variables, while generally the slower compilers did not. The c-systems compiler, the slowest for these tests, did implement register variables, but apparently to no great advantage. Out of curiosity, we also ran a version of regtest( ) that declared only two of the four loop variables to be of register class. For all compilers, the results were the same as for regtest( ). This was educational; it means that, at most, only the first two variables declared were actually kept in registers. This has implications for programming practice: use register declarations, but take

care that variables be declared with the most frequently used first.

For all compilers, the automatic storage class is more efficient than the static. This may come as a surprise to those accustomed to C on 8-bit machines with no stack-relative addressing mode.

Most compilers performed about the same on the looptst( )benchmark—about 60 seconds. The Aztec compiler, however, was significantly faster at 38 seconds. It is unusual that no one else came close to this time, since most benchmarks had several compilers within a few seconds of the fastest time. It turned out that the Aztec compiler generated only two instructions for the empty inner loop, whereas the best the others could do was three instructions.

The Aztec compiler repeated this performance on the array( ) test, coming in twice as fast as the nearest competitor. Here Aztec's performance was due to avoidance of the **imul** instruction in doing subscript arithmetic. In general, the Aztec compiler avoided **imul** in favor of shifts and adds wherever possible. The Aztec compiler also shared the lead in the pointer( ) test with MicroSoft's and Wizard's.

There were no surprises in the tint( ) test. Except for Software Toolworks' C, all the compilers were in a very narrow range, clustered around 35 seconds. There are not many ways to add or subtract two 16-bit integers on a 16-bit machine, and we did not use register declarations in tint( ), which would have given a slight edge to the compilers that support them.

Tlong( ) is another story altogether. The Datalight compiler had its only win here (by a significant margin) at 88 seconds, followed by MicroSoft's and then the Aztec compiler. The real standout in this benchmark was Digital Research's compiler, which came in last by an astounding margin with a benchmark of 808 seconds! It is hard to imagine how it could execute this slowly, over nine times as long as the fastest time. It is especially puzzling because the DRI compiler was a respectable performer otherwise, in fact fastest or essentially tied for fastest on a number of the other tests. If you use longs very much, DRI's is clearly not the compiler of choice!

The results of the optimize( ) benchmark are difficult to interpret. Some of the "lightweight" compilers ran this test quite well, while MicroSoft's did rather poorly, even though we had observed that its optimization was generally very good. Also, the Lattice compiler was fastest by a large margin on this test but was not an outstanding performer on any of the other benchmarks. We looked at the code generated by some of the compilers for a clue and discovered a partial answer. Optimize( ) was especially unkind to those compilers that do not recognize that multiply operations can be replaced by left shift instructions. One saved **imul** instruction can make up for a lot of redundant load and store operations! Actually, this kind of test should always be approached with caution. One of these days a compiler may come along that is so good at global optimizations that it notices when our benchmark functions produce no side effects visible outside the function. It might then be free to replace an entire function with a single RET—very fast indeed!

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The disk I/O benchmarks were really testing part of the library, not the compiler, so we expected a wide range of numbers. What we did not expect was that for many of the compilers, cpychr( ) would be faster than cpyblk( ). When you look at Table 3b, don't overlook the loop count: cpyblk( ) moved twice as many bytes as cpychr( ). The MicroSoft compiler had the fastest time for cpyblk( ), with no other compiler coming close. The Aztec compiler was fastest for cpychr( ), with Computer Innovations' the only close second. The Software Toolworks compiler was abysmally slow on both of these, about four times slower than the generally poor-performing compiler from c-systems. On the other hand, the Toolworks compiler gave a reasonable time for diskio( ), while the fastest time, by a wide margin, was turned in by c-systems' compiler. In fact, the compilers that generally did the best on the various compile-time benchmarks (those from Aztec, MicroSoft, and Wizard) were among the slowest on the random-access diskio( ) test. You figure it out!

The min–( ) benchmarks were intended to test the granularity of the library: we wanted to see how much unwanted "stuff" would be dragged into the .EXE file along with the library functions actually being called. Minmain( ) contains no function calls at all, so the .EXE file size for this test is an indication of the best you can do. The DRI, c-systems, and Lattice compilers were the big losers here, all requiring more than 10,000 bytes of library code to do nothing at all. Not surprisingly, these three were also the worst on the minputs( ), minprtf( ), and minfio( ) tests, although the Lattice compiler's .EXE size remained about the same. The EcoSoft and Wizard compilers both produced amazingly small .EXE files for minmain( ), since the startup code should at least initialize the stdin, stdout, and stderr files. DeSmet's, in third place at 1536 bytes, already includes all the library code needed to support the puts( ) function. That made DeSmet's the smallest .EXE file for minputs( ) by a fair margin, although Wizard's and EcoSoft's were also very small.

Minprtf( ) was the acid test, because the formatting supported by printf( ) usually requires the floating-point package as well as I/O support. Some of the compilers provide an integer-only version of printf( ), however, and we used that option whenever possible since we believe the majority of C applications do not require floating-point support. The compilers that provide this option are giving you more flexibility with an effectively more granular library. They are the compilers from Aztec, Mark Williams (and Control C), Lattice, MicroSoft, and Datalight.

The MicroSoft compiler deserves special mention among these. The other compilers made you specify whether floating-point support was desired, either with a command-line option or via library-search order. MicroSoft's handled this automatically by detecting whether any float or double variables or pointers had been declared in your program, and then linking the math library only if needed. We found this sort of feature to be typical of the Microsoft product.

Using the floating-point version of printf( ) typically added from 2000 to 3000 bytes to the .EXE file size. Choosing the compile option to leave the float library out, Aztec C produced the smallest .EXE file by a large margin, even over the integer-only competitors. Datalight's and MicroSoft's came next and then DeSmet's. The DeSmet compiler produced the smallest .EXE file with the floating-point library included, although the Aztec file was only a few hundred bytes larger. Also, it should be noted that the Software Toolworks compiler is a subset compiler with no floating-point support at all.

For the minfio( ) benchmark, the Datalight, Aztec, and EcoSoft compilers shone the brightest, with Wizard's not far behind. Here DeSmet's .EXE file was a lot larger than the one generated for minprtf( ), even though the float library was not required. This was viewed by all as very strange.

The min–( ) benchmarks, except for minmain( ), are all significant because they give you an idea of how small a small program might be. Since there are very few useful functions to be performed that do not require some console and disk I/O, minmain( ) was included primarily to show the losers in this category in the unkindest light possible. The c-systems and DRI compilers did not fare well at all, requiring 19K and 18K, respectively to say "hello world" via printf( ). Lattice's compiler, a very well thought of product generally, also looked none too good here. The Aztec compiler was the overall winner in this category. The Aztec compiler also had the smallest execution-time benchmark files, requiring only 14K for benchall.exe versus an average of 55K–65K for the others.

Memory Models

The 8086's segmented architecture leads to some tradeoffs between execution speed and addressing range. The way a compiler views the 8086's address space is called the memory model. All the compilers reviewed here support the so-called "small" memory model as the default, and many of them allow no other. The small model allows up to 64K for instructions and 64K total for all kinds of data: heap, stack, statics, and globals. Automatic variables are allocated on the stack, with space dynamically allocated via malloc( ), etc., coming from the heap.

Other possible models are called different things by different manufacturers. Lattice, Aztec, c-systems, Wizard, and Microsoft all provide a model in which code (instructions) can run up to a megabyte (the maximum allowed by the 8086), but data is limited as in the small model. Lattice, Aztec, c-systems, and Wizard provide a model that limits code as in the small model, but the heap may extend to a megabyte, the stack can grow to 64K, and statics and globals together can take up 64K. DRI and Computer Innovations, in addition to the just-mentioned four, provide a model allowing code up to a megabyte and data as in the preceding model. Wizard and Microsoft have a model that extends this last model by allowing more than 64K of combined statics and globals (although no single item may be greater than 64K), in addition to the one-megabyte code and heap spaces; the stack is still limited to 64K.

Floating-point and 8087 Results

Vendor	tflt	tdbl	EXE size	8087	inline	Notes
8087 series:						
Aztec (Manx)	119.1	141.0	7584	Y	N	m87.lib
Aztec (Manx)	149.1	168.5	10000	N	N	m87s.lib
c-systems	145.0	153.7	22424	Y	N	
c-systems	59.9	68.3	20956	N	Y	
Computer Innovations	59.2	68.3	10027	N	Y	
DeSmet	119.0	128.3	12288	N	N	stdio7.s
Digital Research	67.3	76.5	22528	N	Y	
Ecosoft	290.5	161.7	10828	Y	N	
Lattice	1675.8	1256.0	17452	Y	N	didn't use 8087
Mark Williams	53.7	62.9	9632	N	Y?	-rndp -vsmall
Microsoft	81.0	89.7	21172	Y	N	/fpc
Microsoft	81.0	89.6	14148	N	N	/fpc87
Microsoft	55.7	64.2	20932	Y	Y	/fpi
Microsoft	55.6	64.2	13908	N	Y	/fpi87
Wizard	350.0	209.0	11788	Y	N	
Wizard	368.7	72.0	11916	N	Y	-f
Floating-point series:						
Aztec (Manx)	78.8	81.0	9136	N		m87.lib
Aztec (Manx)	80.6	83.2	10000	Y		m87s.lib
c-systems	95.1	78.6	22424	Y		
Computer Innovations	173.1	166.0	11453	N		
Datalight	121.8	71.1	10068	N		
DeSmet	97.8	79.2	14848	N		
Digital Research	83.6	61.7	22016	N		
EcoSoft	129.6	105.8	10878	Y		
Lattice	112.0	84.2	17452	Y?		
Mark Williams	98.8	94.3	13137	N		
Microsoft	91.7	101.9	21172	Y		/fpc
Microsoft	25.6	45.6	16580	N		/fpa
Microsoft	92.6	102.6	20932	Y		/fpi
Wizard	23.1	71.4	11788	Y		

The floating-point series are with loop counts of 600, run at 7.16MHz.
The 8087 series are with loop counts of 6000, run at 4.77MHz.
The rightmost column indicates whether in-line code is supported. The column headed "8087" indicates, for floating-point results, whether the test runs faster with an 8087 present, and, for the 8087 results, whether it works if an 8087 is not present.

Table 4
Floating-point and 8087 Results

Documentation and Support:

Vendor	Usability	Readability	Support
Aztec (Manx)	2.83	**3.72**	1.88
Control C	3.17	2.87	1.56
c-systems	2.50	2.55	2.19
Computer Innovations	3.17	2.83	2.50
Datalight	1.00	1.03	.63
DeSmet	2.33	2.17	3.44
Digital Research	3.33	2.58	**4.06**
EcoSoft	2.17	2.05	1.56
Lattice	3.67	2.97	2.81
Mark Williams	3.17	2.87	1.88
Microsoft	**4.67**	**4.02**	3.13
Software Toolworks	1.83	1.33	1.56
Wizard	3.33	2.85	**4.38**
Interpreters:			
C-terp	2.50	1.83	.63
Instant C	3.00	1.25	1.56
Run/C	2.50	**3.87**	.94

Table 5
Documentation and Support

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Powerful Commands

Epsilon has over 125 commands instantly available. Epsilon can manipulate words, sentences, and paragraphs easily. Epsilon will automatically save text you have deleted in a "ring" of kill-buffers, so that you can retrieve it later. It will help you avoid syntax errors by displaying matching parentheses. *And best of all, Epsilon's macros let you define your own commands, which can be loaded automatically each time you start Epsilon.*

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	Epsilon	Brief	Mince	Emacs
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Write 21K file	2.11	14.30	6.05	7.95
Next Screen	.19	.24	1.33	1.80
String Search	3.85	7.04	4.49	8.41
I-Search	3.85	--	--	8.73
First Help	8.30	12.33	--	--
Other Helps	.20	11.64	--	--

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The Wizard and Lattice compilers each have an option that permits the compiler to generate much better code for the large models, if the programmer is willing to live with certain restrictions regarding pointer arithmetic. These two compilers also allow very small programs to be changed to .COM files. Such programs must fit all code and data into 64K.

Microsoft is currently the only one of the 13 reviewed manufacturers supporting "mixed-model" programming, although others indicate that it is high on the to-do list. Mixed-model programming allows certain pointers to be declared "near" or "far," allowing you to use a pointer from a model different from the model of the rest of the program. You can write a program that uses the small model with its speed benefits and make only certain pointers of the time-consuming "far" variety to gain access to very large arrays.

Floating-Point and 8087 Support

Although C is presently most often applied to problems that don't require any floating-point arithmetic, the language does support and define the use of "real" numbers. Of the 13 compilers reviewed (see Table 4, page 43), all but one, Software Toolworks C, support floating-point math, and Toolworks expects to have it available by the time you read this.

The remaining 12 all support both float and double data types as 32- and 64-bit quantities, respectively. Nearly all use the IEEE floating-point standard to represent float and double. This makes it relatively easy to take advantage of an 8087 math chip (which also uses the IEEE standard). Datalight's is the only compiler we reviewed that did not offer any way to take advantage of the 8087. Lattice's compiler documentation indicated that its library was "sensing," but our results indicated that it did not use the available 8087.

A sensing library is a library of floating-point functions that use the 8087, if one is present, and do the required operations in software if not. This means that you, the programmer, don't have to know in advance if your program is going to run on a machine with an 8087.

Another way of supporting an 8087 is to use a library that requires the presence of an 8087. Compared to the sensing library, this buys you a little time (the time the sensing library takes to decide whether there's an 8087 for it to use) and some 2K–7K of code (the software floating-point routines). Or you can generate 8087 instructions in-line like integer operations. This saves the time needed to make the function call.

It is possible to execute an 8087 instruction in a machine not having an 8087. What happens is that the 8086 traps to a user-provided interrupt routine. This routine may emulate the 8087 and return. This allows the compiler to generate in-line instructions and still not require an 8087, but to use one if it's available. Only Microsoft's compiler implements this type of an emulation scheme.

Documentation

We reviewed all documentation and packaging for each

compiler. To be consistent, we developed "benchmarks" for documentation, with a grading system consisting of two main categories: usability and readability.

Usability

The usability category covered the overall packaging of the documentation: the organization and quality of presentation that make the documentation easy or difficult to use. The items that contributed to the usability score were the following:

- Packing list (P/L): Was a list of all manuals, disks, etc., included so that you could confirm that you had received everything?
- Disk contents (DISK): Was a list of all disks and their contents included? Often one was included, but buried in the manual and hard to find.
- Binding (BIND): How was the documentation received from the vendor? We saw everything from loose pages (not even clipped or stapled) to multiple 3-ring binders in attractive cases.
- Table of contents (TOC): Was there one? How complete was it?
- Index (INDEX): Was an index included, and how complete was it? Believe it or not, some vendors don't want you to locate anything in the documentation, as proven by the fact that they don't index their manuals!
- Error codes (ERR): Was a list of error codes generated by the compiler present, and how useful was it?
- Startup (START): Was a getting-started section supplied for those who need this level of support? Also considered here: the quality of instructions on batch files for installation, sample "test" programs to try out the compiler, and sample batch files for operation.
- Operation (OPER): Was a compiler-operation section included, how complete was it, and could you find each compiler option without rereading the entire section?
- Libraries (LIB): Was a section describing the libraries supplied, and how easy was it to find a particular function? This is where a good index helps, but at least the functions ought to be in some order, not at random! The CI-86 compiler included a brief summary of the functions in its table of contents—bravo!

Readability

Readability pertained to clarity of presentation and to the ease with which the material could be understood. To establish some method of consistent grading, we picked three library functions and subjectively graded the presentation on each function across all compilers. We picked fopen( ), fread( ) (where supported), and printf( ). We looked for such things as good examples, clear definition of all parameters, clear definition of return values, error returns, notice of deviation from standards, and a good explanation of the function. We also gave credit if only one function was printed on a page, making it easier

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to find and read. Cop-outs such as "see K&R for description of this function" sat very poorly with us.

Table 5 (page 43) shows the numerical scores we arrived at for documentation. The Microsoft manuals were the best on virtually every point. The Wizard, Lattice, and DRI manuals should be usable over the long run, and the Aztec book was very readable.

User Support

The best software product is of marginal value if it is not well supported. We attempted to review the kind and quality of user support available for the compilers reviewed. This included contacting support groups for most of the compiler publishers to evaluate their responsiveness.

Although you should not expect the same level of support for an MSDOS compiler as you might for a compiler running on a large mainframe, some of the same support features should be available. Ideally, support should reflect some modularity, so those who need full support can obtain it, while those who need only occasional assistance don't have to pay for support they won't use. We attempted to evaluate user support based upon several criteria that we determined to be important. The numerical results are shown in Table 5. Here is a discussion of the criteria.

Bug List

Most of the compilers did not have available a *current* list of known bugs. Some did indicate problems known but not yet fixed as of a particular release, either in a read.me file or in the documentation. Ideally, what we wanted to see was a regular update describing current bugs, the expected fix date, and any work-arounds. This would be a big help at two in the morning when you are under pressure to complete a big project, but are stopped dead by a compiler bug. It also ought to help the customer service group by reducing the number of times the same bug is reported.

Registration

Most vendors supplied a means to register the compiler so that the buyer could receive notices of future releases. Some were even postpaid. We had no means of verifying that new release notices would appear in the mail, but past experience indicates that sometimes such notices are sent and sometimes not, depending on the vendor.

Update Subscription

Only one vendor (Wizard) offers a fixed-price annual subscription service for all bug fixes and updates. Many others indicated that updates were available but were charged on a per-update basis. The Wizard approach has

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Phone Consultation

Phone-in consulting service was available from all vendors, but some vendors required a serial number to gain access and others required money before giving the buyer a phone number to call. Although it is certainly not unreasonable to charge for support, many vendors bundle phone support into the basic product. We found that some vendors restricted calling hours.

Support Quality

All the reviewers made notes when they called vendors for support, and the documentation group also attempted to contact the support personnel for each vendor. We found a wide range in quality of support. Sometimes we were referred to the author of a compiler. That should get you qualified technical support, but we felt it to be a negative; it meant the technical support was dependent on one person, and if that person is unavailable, you're stuck. On the other hand, talking to a "support person" who doesn't know C makes one very uneasy. We found that the support team at Wizard offered by far the best technical assistance.

In Table 5 you see an attempt to assign numbers to our experiences with the vendors in these areas of technical support. The clear winners here were Wizard's, DRI's, DeSmet's, and Microsoft's compiler support.

Compiler-specific Comments

The following comments, arranged by compiler, elaborate on the major items not already discussed or easily discernible from the tables: the quality of the documentation, standards issues, user support, overall benchmark performance, and summary remarks.

Aztec C86

Aztec C86 was easily one of the fastest compilers overall and handled array referencing more efficiently than any other compiler. Our results indicated that its library provides a lot of flexibility, allowing you to generate small .EXE files. It was the best in this area. The Aztec compiler provides an integer-only version of printf( ). There are several large-memory models to choose from. A make utility is included.

There was a general problem with the benchmarks: the main( ) routines used a cast to produce a null pointer to function returning an int — (int (*)( )) 0. Some compilers could handle it; many others couldn't. Aztec C86 couldn't handle this function cast in main( ), but it gave an excellent error message when it tried.

The Aztec manual had one major problem: it has no

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index. Otherwise it rated above average, though we thought it needed more white space for readability. Aztec did include a section on making your code ROMable, very useful to some, and it had good examples in the library descriptions, although these tended to describe more than one function at a time. This does save repeating the same text over again, but it makes it a little difficult to extract specifics about a particular function. A new manual is available (received too late for review); among the utilities included are editor, debugger, make, Aztec to .OBJ format converter, CRC utility, archiver, squeezer, grep, and hex generator.

Control C CC-86

Control C's compiler is a copy of Mark Williams C (MWC), documentation and all, so we'll refer you to our comments on MWC. Apparently, Control C is doing the port of the Mark Williams compiler to CP/M-86 and, as part of the arrangement, is able to provide the MSDOS version to the outside world. The only comments we'll make specific to the Control C compiler are that one of the six disks in the original package we received had a defect and that the Control C package did not include the function-key pad overlay for the debugger, as the Mark Williams package did.

c-systems 8088 Software Development Package

Although generally slow, the c-systems compiler turned in the fastest time in the disk I/O test. It did not do well in tests of generated-code size. c-systems provides several large-memory models. The c-systems compiler does not support fgetc( ) in stdio.h, even though fputc( ) is supported. Consequently, fgetc( ) was coded as a module, rather than as a macro, using getc( ).

The c-systems manual contained a neat trick for compiling multiple modules using wildcards. Other compilers support wildcards in the command line; c-systems uses the **for** batch command from the command line. For example:

```
A>for %f in (min*.c) do cc %f
```

This technique can be used with any compiler. c-systems' compiler was about average in the area of documentation. It didn't include a binder, and the print quality was only fair. The installation section was too brief, but the operation section was well done. It did include a detailed list of differences from the standard, something many did not. The library descriptions lacked examples and could use more information on return and error values. There were problems using drivers; occasionally they would not run for no apparent reason and they only used the first 128 bytes of the environment string so the INCLUDE variable was not always findable; the compiler has PL/M compatibility.

Computer Innovations Optimizing CI-86

The CI-86 compiler performed in the middle range on nearly all the benchmarks, walking away with the copychr disk I/O test. One nice feature of the CI-86 compiler is that numerous paths are provided for interfacing to the operating system. For instance, you can initialize and release interrupt routines such as might be required for writing a communications program.

Computer Innovations provides a large-memory model, although when we used it, it would not allow pointer arithmetic on a multiply-dimensioned array across dimensions. The documentation explains this strange behavior, stating that without the functions that convert pointer to long (ptrtoabs( )) and long to pointer (abstoptr( )), "big-model pointer arithmetic assumes the data segments are the same for the pointers." The compiler did give a reasonable error message when an input data file was not found. The CI-86 compiler doesn't allow ++ or -- on float or double variables. For example:

```
double d; d++;
```

did not work, while

```
double d; d += 1;
```

did work.

We judged the Computer Innovations manuals above average. They included a good approach in the table of contents: a one-line description of each library function, serving as a quick-reference guide. Their library descriptions were well done, with examples and notes on DOS applicability. The compiler-operation section was too brief, and no listing of compiler error messages was included.

Datalight C

The old MSDOS Small-C compiler distributed by Datalight was a port of the public domain Small-C compiler for CP/M. The new C Compiler, which is a full implementation of the C language, stood out in a number of areas. It came in first or tied for first on several tests, standing in a class by itself on the long-arithmetic benchmark. Datalight provides an integer-only version of printf( ).

The Datalight compiler appears to implement real block scope for declarations. Function xmalloc( ) was declared as extern char *xmalloc( ) inside main, and this declaration was not in force in later functions, leading to a "definition inconsistent with prior use" error when the function was called. We view this as appropriate, but it is not clear what behavior K&R calls for, and most of the other compilers did not catch this error.

The Datalight compiler could not compile the global definition

```
char null_strg[ ] = { "" };
```

It had no problem when it was changed to

```
char null_strg[1] = { "" };
```

The documentation that came with the new Datalight compiler was a significant improvement over the previous version, as was the compiler itself. The packaging was still

low-budget, like the compiler—56 8½-by-11 spiral-bound pages with small, difficult-to-read print. All the essentials were there, though. There was a usable table of contents and an index, the few supported error messages were all described, there was a setup section with a sample program, and some of the function definitions included examples. Overall, not bad for a $50 compiler.

DeSmet C

The DeSmet compiler was generally mid-range in speed, coming in above average in the screen I/O tests and losing the floating-point math test. It produced the smallest .EXE files in certain of the code-size tests. The compiler is supported by a good user group, and there was a bug list.

No error message was produced when an input data file was not found—the compiler just went to sleep! DeSmet's compiler does not like really long comments; an error message was generated at line 28 after the opening /*.

DeSmet's manual is a low-budget product. Its pages were not bound nor even stapled; they lacked an installation section, and although the DeSmet package supplied a lot of software, nowhere is there a list of what you should have received in the package. The manual also omitted an index and didn't organize the functions as we would have liked, with one function on a page. The descriptions were brief, but they did include examples.

Digital Research DRI C

Although the DRI compiler was among the faster overall, it dawdled through long arithmetic. The compiler performed poorly on the tests of library granularity. DRI provides a large-memory model, and DRI's support got high marks.

DRI's compiler had no problem with the function cast in main( ). No timer function and no access to DOS interrupts were provided; an assembler is required, but rasm86 was included, and the manual documented the assembly and linkage process very well, including an example. Capital letters on the command line were converted to lower case before being passed to main( ).

DRI's compiler was the only one to report an error for two statements in doc1000.c that defined and initialized global arrays. Both initialization lists included a trailing comma, as in:

```
int array[ ] = { 1, 2, 3, 4,
        5, 6, 7, 8,
    };
```

The output file produced by cpyblk( ) was too small because fread( ) returned zero instead of the actual number of bytes read on the final block. The block size was 1024 bytes, so the last block would have been a short one.

Digital Research put a good documentation package together. They provided a reprint, in their own binding, of K&R. The index was good, and a nice error list appeared in an appendix. The getting-started and operation sections were well done, with good tables and examples. The library function descriptions could have been better organized,

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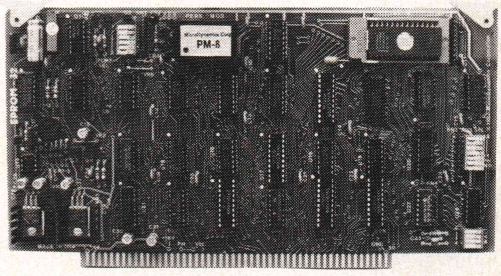

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See Dec. 1983 **Microsystems** for a review of the EPROM-32.

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though, and should have included examples instead of directing the reader to K&R for descriptions of functions.

EcoSoft-C

The EcoSoft compiler was not dazzlingly fast nor distressingly slow on the benchmarks. It did well in the code-size tests, producing a remarkably small .EXE file in the minmain( ) test. The library had no fgetc( ) nor fputc( ). These should have at least been defined as macros in stdio.h. We appreciated the fact that EcoSoft included the source for CC, its driver program. Given that they had written a fairly good book on C, we expected good documentation from EcoSoft. We were disappointed to find a very short table of contents and no index. We found the documentation difficult to use. The getting-started and compiler-operation sections were too brief. The library functions did not include examples and were not terribly well organized for easy reference. The compiler was hard to use relative to others in our environment without recompilation of the CC driver.

Compilers

Wizard C V. 2.1
Wizard Systems Software
11 Willows Ct.
Arlington, MA 02174
(617) 641-2379

DeSmet C V. 2.4
C Ware Corp.
P.O. Box C
Sunnyvale, CA 94087
(408)720-9696

Lattice C V. 2.14
Lattice
P.O. Box 3072
Glen Ellyn, IL 60138
(312) 858-7950

Datalight C V. 1.0
Datalight
11557 8th Ave NE
Seattle, WA 98125
(206) 367-1803

8088 Software Dev Pkg V. 2.08a
c-systems
P.O. Box 3253
Fullerton, CA 92634
(714) 637-5362

Optimizing CI-86 V. 2.20k
Computer Innovations
980 Shrewsbury Ave. #310
Tinton Falls, NJ 07724
(201) 542-5920

C Programming System V. 2.0
Mark Williams Co.
1430 W. Wrightwood
Chicago, IL 60614
(312) 472-6659

Microsoft C V. 3.0
Microsoft
10700 Northup Way
Bellevue, WA 98004
(206) 828-8088

Aztec C86 V. 3.20c
Manx Software Systems
Box 55
Shrewsbury, NJ 07701
(201) 780-4004

DRI C V. 1.1
Digital Research
P.O. Box 579
Pacific Grove, CA 93950
(408) 649-3896

CC-86 V. 2.0
Control C Software
6441 SW Canyon Ct.
Portland, OR 97221
(503) 297-7153

Ecosoft-C V. 2.0
6413 N. College Ave.
Indianapolis, IN 46220
(317) 255-6476

Software Toolworks C V. 3.2
Software Toolworks
15233 Ventura Blvd., #18
Sherman Oaks, CA 91403
(818) 986-4885

Interpreters

Instant C V. 1.00
Rational Systems
P.O. Box

Run/C V. 1.11
Age of Reason
318 E. 6th #123
New York, NY 10003

C-terp V. 1.04
Gimpel Software
3207 Hogarth Lane
Collegeville, PA 19426
(215) 584-4261

Table 6
Addresses of Compiler and Interpreter Vendors

Lattice C

The Lattice compiler had some strengths and weaknesses (e.g., screen I/O) in execution speed. Although one benchmark is inadequate to assess a compiler's optimization, it should be noted that Lattice won the optimization test hands down. Lattice didn't do particularly well on the code-size tests, but it is one of the few vendors providing the flexibility of an integer-only version of printf( ). Lattice also allows small programs to be changed to .COM files and provides several large-memory models and an option that allows the programmer to trade some pointer-arithmetic facility for better generated code.

The LC program could not handle directory path names in its file list, even though LC1 and LC2 allowed this. The math library was required to do any floating-point stuff, not just transcendentals, etc. Also, the math library had to precede the std library in the search order. The manual documented neither of these facts. Having long supported C for MSDOS, Lattice has produced above average documentation for its compiler and included a good index into the functions. While the installation and getting-started section was brief, it was adequate. The compiler-operation section was good, but finding the utilities operations was a little difficult; these should have had their own sections. The function descriptions were fairly well done but lacked examples. The function descriptions did include a caution paragraph, which is good. This was the only vendor to supply a packing list with the package.

Mark Williams C Programming System

The Mark Williams compiler was the fastest compiler in the screen I/O tests. MWC provides an integer-only version of printf( ). We couldn't determine from the manual what the memory model options were when using MWC object format (−vsmall and −vlarge also force Microsoft object format). There appeared to be no way to specify the desired memory model with MWC object format, implying that the small model was the only one available. An attempt to cast a long to a char led to the following compiler message:

```
113: At 591: Fatal error: no match, op = 62
```

This was not too helpful, and the C syntax *was* legal. And there was no list of errors in the manual, with or without probable cause.

This compiler had a fairly well done manual, with a sample program to compile and run during installation.

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The function descriptions were reasonably well done and readable. There could have been more examples, and many functions were packed into one description, making it hard to extract pertinent information.

Microsoft C

The Microsoft compiler was fast in nearly all categories, although it didn't do well on the random-access diskio( ) test. We found it to be a carefully designed compiler, very well documented, and with some well-thought-out features. It provides an integer-only version of printf( ) and a variety of large-memory models, plus mixed-model programming. This last feature and 8087 emulation are two features only Microsoft offers.

Microsoft's compiler set a very high standard for software documentation. Two full binders were included: a complete language reference manual plus the compiler and library reference manual. The accompanying slip case folded down to form a book stand. We found it difficult to fault any aspect of Microsoft's documentation package, except for the slight jitter in their laser printer. One experienced C programmer in the group noted that he had never spent more than a couple of minutes with the documentation, because he was able to find what he needed very quickly.

The Microsoft compiler includes the Bessel functions; has excellent Unix/Xenix portability; and is very easy to use.

C Interpreters

In addition to the compilers, we evaluated three C interpreters: C-Terp, Instant C, and Run/C. We were fairly demanding of the interpreters, and our comments should probably be taken as an experienced programmer's view. A beginner might be happier than we were with these products. They were generally faster than the compilers when it came to making a change and seeing what the results were, and that's important when you're learning a language. We did, however, have some complaints.

All three forced some rewriting of our benchmark programs. All three lacked some run-time support modules, in particular fread and fwrite. (C-Terp supplied them, but not in the standard release versions.) All three were memory-hungry, requiring some 300K to execute. We found at least one bug in each of the interpreters in the process of running our benchmarks, once we got the benchmark code in a form each compiler would accept. Of the three, Run/C was the least expensive, but also the least flexible. Block comments had to start in column one with only the "/*" on the line; the terminating "*/" had to meet similar constraints. Run/C was also slow in loading and executing. When we specified a program from the command line, Run/C loaded it, then checked for errors; when one was found, Run/C aborted interpretation, and we lost the (significant) load time. Run/C could not handle pointers to functions.

Instant C was fastest and had most of the features we felt we couldn't get along without,but we found that its editor got in the way. We were frustrated by its limitation to two array indices and by its small work area. It had nice, APL-like immediate-mode variable output that was very handy during the debug phase.

C-Terp was the most flexible and came closest to implementing the complete language. It had the ability to interface to functions written in assembly language, although requiring a compatible compiler to implement the interface. Assembly-language interface is promised for the near future for the other two interpreters. Unfortunately, C-Terp's documentation was sparse, a problem for beginners.

These tools are useful for checking out a short algorithm quickly, but not as the sole language implementation for developing complex pieces of software. You can learn C from them, although a purist might argue that you don't know C until you have worked with the full language. Of these interpreters only C-terp offered one of C's greatest strengths, the flexibility of using pointers as data.

There are three questions to ask yourself in considering buying one of these interpreters or recommending it to others: Can your programming needs be met by an interpreter alone? If you're planning to develop significant software in C, they probably can't. Is it worthwhile to you to purchase both an interpreter and a compiler? It may well be; they address different needs. And if you intend to buy an interpreter, which one? We've provided some material here for the beginning of your evaluation process, but note that we only looked at three C interpreters. And this is an experienced programmer's view of these products. For the benchmark results see Table 8 (below).

Interpreter:	tint	tlong	array	pointer	looptst	opt	fibtest	sieve
C-terp	.2	.2	22.1	28.0	41.7	126.4	54.5	329.2
Instant C	<0.1	<0.1	<0.1	<0.1	.8	1.6	19.2	4.4
Run/C	2.4	2.5	115.2	113.1	205.3	815.5	252.5	407.3

Table 8
Addresses of Compiler and Interpreter Vendors

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RECENT DISCOVERIES

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PROLOG-86 - Learn fast. Standard, tutorials, samples of Natural Language. Exp. Sys. MSDOS $125

TLC LISP - "LISP-machine"-like. all RAM, classes, turtle graphics 8087 CPM-86. MSDOS $235

WALTZ LISP - "FRANZ LISP" - like, 611 digits, debugger, large programs. CPM80 MSDOS $159

MicroProlog - improved MSDOS $235

BASIC

ACTIVE TRACE, DEBUGGER - BASICA, MBASIC, interactive, well liked MSDOS $ 79

CADSAM FILE SYSTEM - full ISAM in MBASIC source. MSDOS $150

BASCOM-86 - Microsoft	8086	279
CB-86 - DRI	CPM86, MSDOS	419
Data Manager - full source	MSDOS	325
InfoREPORTER - multiple	PCDOS	115
Prof. Basic - Interactive, debug	PCDOS	89
TRUE BASIC - ANSI	PCDOS	125

Ask about ISAM, other addons for BASIC

EDITORS FOR PROGRAMMING

BRIEF Programmer's Editor - undo, windows, reconfig. PCDOS $195

VEDIT - well liked, macros, buffers, CPM-80-86. MSDOS. PCDOS $119

C Screen with source	86/80	75
Epsilon - like EMACS	PCDOS	195
PMATE - powerful	8086	185
XTC - multitasking	PCDOS	95

COBOL

Microsoft Version II - upgraded. Full Lev. II, native, screens. MSDOS $500

Dig Res-decent	MSDOS 525
Macintosh COBOL - Full.	MAC 1850
MBP - Lev II, native, screen	MSDOS 885
MicroFocus Prof.-full	PCDOS call
Ryan McFarland-portable	MSDOS 695

C LANGUAGE

C-terp Interpreter by Gimpel, full K&R, .OBJ and ASM interface. 8087 MSDOS $275

INSTANT C - Interactive development - Edit. Source Debug, run. Edit to Run - 3 Secs. MSDOS $445

"INTRODUCING C" - Interactive C to learn fast. 500 page tutorial. examples, graphics PCDOS $ 95

Wizard C - Lattice C compatible, full sys. III syntax, lint included, fast, lib. source. MSDOS $450

MSDOS C86-8087, reliable	call
Lattice C - the standard	call
Microsoft C 3.0 - new	279
Williams - debugger, fast	call
CPM80 - EcoPlus C-faster, SLR	275
BDS C - solid value	125

MEGAMAX C - native Macintosh has fast compile, tight code, K&R. toolkit, .OBJ, DisASM MAC $275

MACINTOSH Hippo II	375
Consulair's MAC C, toolkit	395

Compare. evaluate. consider other Cs

C ADDONS

APPLICATION TOOLKIT by Shaw - Complete: ISAM, Screen, Overlay mgnt, report gen. Strings, String math. Source. CPM, MSDOS $395

COMMUNICATIONS by Greenleaf ($159) or Software horizons ($139) includes Modem7, interrupts, etc. Source. Ask for Greenleaf demo.

C SHARP Realtime Toolkit-well supported, thorough, portable, objects, state sys. Source MANY $600

CIndex + -full B+Tree, vari. length field. Source, no royal. MSDOS $369

dbVista FILE SYSTEM - full indexing, plus optional record types, pointers. Source, no royal. MSDOS $450

CHelper: DIFF, xref, more	86/80	135
CTree - source, no royal	ALL	369
dBC ISAM by Lattice	8086	229
Greenleaf-200 +	MSDOS	159
OTHER: C Utilities by Essential	MSDOS	129
PHACT-up under UNIX, addons	MSDOS	225
ProScreen - windows	PCDOS	275
SCREEN: CURSES by Lattice	PCDOS	125
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File MGNT: BTrieve - all lang.	MSDOS	215
Micro: SubMATH - FORTRAN full	86/80	250
MetaWINDOW - icons, cup	PCDOS	139
PANEL - many lang. term	MSDOS	249

OTHER LANGUAGES

ASSEMBLER-ask about Turbo ASM ($95), ED/ASM ($95) - both are fast, compatible. or MASM ($125), improvements.

BetterBASIC all RAM, modules. structure. BASICA - like PCDOS $185

SNOBOL4 + -great for strings, patterns. CPM86, MSDOS $ 85

MacASM - full, fast, tools	MAC	115
Assembler & Tools - DRI	8086	159
PL1-86	8086	495
PCFORTH - well liked	MSDOS	95

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Pfinish - Profile by routine	MSDOS	345
Polylibrarian - thorough	MSDOS	95
PolyMAKE	PCDOS	95
ZAP Communications-VT100. TEK 4010, full xfer	PCDOS	65

DEBUGGERS

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Advanced Trace 86 Symbolic	PCDOS	149
Atron Debugger for Lattice	PCDOS	395
CODESMITH-86 - debug	PCDOS	129
PFIX-86 Debugger	MSDOS	169
TRACE86 debugger ASM	MSDOS	115

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Software Toolworks C

The Software Toolworks compiler for MSDOS is a port of their C80 compiler for CP/M. The original compiler was a descendant of Small C, adding such features as multi-dimensional arrays and structures. The MSDOS version does not currently support the long, float, or double data types. Longs and floats will be available in an optional "mathpack," currently under development. The lack of these data types meant that we could not run some benchmarks, and the prtf( ) benchmark had to be modified so that the same number of lines were produced, but all longs, floats, and doubles were changed to ints.

Although the compiler does not support longs, it does support fseek for files in excess of 64K. The file position has to be passed as an array of two ints. As a result, a special version of the diskio benchmark was written; the principal changes were to make all longs arrays of int and to use a file created with the Lattice compiler to obtain the random position to seek to. The seek addresses were identical to those used in other benchmarks. The compiler also did not support initialization of data of class auto. Several of the benchmarks had to be changed to account for this feature.

Other unimplemented features included: typedef, bit fields, and line control (#line). Major restrictions included: function calls had to have the same number of arguments as the called function definition, which resulted in a kludge in printf, fprintf, sprintf, scanf, fscanf, and scanf; declarations were allowed only at the start of a function; #define could not have arguments. The printf kludge required that stdio.h be included for minprtf. The compiler supported the small model only (64K of code and 64K of data). The compiler included a function profiler that recorded the total number of calls to a function and the time spent in each function. In contrast to the C80 compiler, this compiler did not support in-line assembly code, although details of the assembly language interface were provided in the manual. This was clearly a subset compiler, with poor documentation. There was an index, though

Aztec	$199 – Pro Package $500
Microsoft	$279
Computer Innovations	$395
DRI	$350
Mark Williams	$495
Control-C	$500
c-Systems	$199
Wizard	$450
DeSmet	$109 + $50 (debugger) + $35 (DOS LINK)
Datalight	$60
Ecosoft	$49.95
Lattice	$425
Software Toolworks	$49.95 + ($29.95 float)
C-terp	$300
Instant C	$495
Run/C	$149.95

Table 7
Compiler and Interpreter Prices

there were many functions to a page, making it difficult to find and read the descriptions. The function descriptions were terse and devoid of examples, again making it difficult for a new user.

Wizard C

Wizard's was generally a fast compiler. It supports a variety of large-memory models, lets the programmer trade some pointer-arithmetic capabilities for better generated code, and allows very small programs to be changed to .COM files. Wizard's got the highest marks for support.

Field width specification did not work for character conversions in printf( ); e.g., printf(%17c,c) produced one character, not 17. Careful reading of K&R leaves us with small doubt that Wizard is in the wrong. It is certainly safe to say that if Wizard maintains that field width is not supposed to work with %c, then they stand alone.

The Wizard compiler was an obvious port down from Unix, as the documentation reflected Unix throughout. While the getting-started section was small (one page) and no installation section was included, we appreciated the 22 pages of error messages. The function descriptions were readable, but like functions were grouped together and there were no examples.

Excellent diagnostics were provided for portable code; to increase portability from Unix, the library included Unix functions that have little meaning but are a pain to remove (e.g., getpid). The compiler supports anachronisms (=+ . . .); supports the use of libraries for other compilers by changing call and return specifics; and includes lint. It has PL/M compatibility and is very easy to use.

Miscellaneous Comments

Microsoft, Wizard, Mark Williams, Control C, Ecosoft

These all had drivers that allowed the compilation of several files (assembly of assembly language files) and optional linkage of the files. This proved to be a great boon.

Mark Williams, Control C

Excellent source level debuggers and very nice examples of usage in the manual and on disk; does not interfere with screen I/O.

DeSmet, Aztec, c-systems

Included source or symbolic level debuggers, but we did not test them.

Microsoft, Lattice, Wizard

Support use of third party or optional source level debuggers, such as SYMDEB.

Aztec, Wizard, Lattice, DeSmet

Provide for generation of ROMable code.

Microsoft, Aztec, Mark Williams, Control C, c-systems, DeSmet, Wizard

The first six used environment to pass "usual" options to compiler; Wizard used a file and this approach was slightly preferred. DeSmet and c-systems had bugs in usage.

Microsoft, Aztec, Wizard, Contol C, Mark Williams

Support new structures (passing, assigning, and returning) and enum and void.

Aztec, DRI

Could not locate math functions in table of contents; includes overlay support.

Mark Williams, Control C

Unable to determine from the documentation what the specifics of the large model were.

Aztec, CI-86, Wizard, Software Toolworks

Library source included or available.

Summary

Were we objective? We all had our preferences and unequal experience with the compilers going into the review; we can't expect that we entirely overcame them. But large amounts of data can swamp out fairly extreme priors, and it was hard to deny the numbers we were getting.

So, who won? If you pressed us to declare a winner, we'd probably say the Microsoft or Aztec compiler. But the Wizard compiler had excellent diagnostics; it would be easier writing portable code with it than with any other compiler we tested. And the Mark Williams compiler had the best debugger. Our data would support different results, depending on how you chose to weight the features we assessed. No two programmers will weight them the same way. And we took almost no account of price. For addresses of compiler vendors see Table 6 (page 54); for compiler prices see Table 7 (page 50).

DDJ

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A Peephole Optimizer for Assembly Language Source Code

by David L. Fox

The need for small fast programs is a constant of computer programming. Unfortunately, small fast programs tend to be difficult to write and maintain. As a result a programmer often has to make a choice between assembly language and a high-level language.

D. E. Cortesi, who has discussed this problem in several "Dr. Dobb's Clinic" columns,[1] has pointed out that an optimizing compiler is a powerful incentive to choose a high-level language. The compilers currently available for microcomputers, however, fall far short of the state of the art in terms of the size and speed of the code they produce. In fact, many of these compilers produce code that could be improved by the simple technique of peephole optimization.

In this article, I describe a standalone peephole optimizer that can post-process the output of any compiler producing assembly language source code. The program is written in C and has been compiled with Software Toolworks' C/80 compiler. According to a published benchmark comparison,[2] in terms of both code size and execution speed this is one of the better C compilers available for CP/M. Nevertheless, peephole optimization can improve its output, and I will use it for the examples in this article.

David L. Fox, 2140 Braun Dr., Golden, CO 80401

Program Optimization

The term *optimization,* as it is usually applied to programs, is actually something of a misnomer: it derives from the word *optimum,* meaning the best possible, and no program optimizer or optimizing compiler can seriously claim to produce the best possible code. A more realistic goal is merely to improve the code.

The greatest improvement in a program usually comes from using a better algorithm. If you are not convinced of the importance of choosing an efficient algorithm, I suggest that you write two routines to sort an array of numbers, one using a bubble sort and another using a Shell sort. Use them to sort an array of 1000 numbers. The bubble sort, which requires a time proportional to the square of the number of items sorted, will run tens or even hundreds of times longer than the Shell sort, which requires time proportional to $n^{1.5}$ to sort n items. Unfortunately, the choice of algorithm is not something that we can easily mechanize. If you want a substantial improvement in the performance of a program, rewriting it using a better algorithm may be the only choice available.

Algorithms for finding and replacing regular expressions are well known. Common inefficiencies in compiler output can be specified as regular expressions. So . . .

The more modest improvements obtained by the means discussed below should not be dismissed, however, because they frequently lend themselves to implementation by a program (an optimizing compiler or a separate optimizer) and require little

effort on the part of the programmer. Many of these improvements involve recognizing specific constructions in the input and replacing them with more efficient code in the output. This process is easily mechanized.

One rich source of potential improvement in compiler output is removing the recalculation of values that are already available. For example, a straightforward compilation of a statement such as

```
a[i] = b[i] + c[i]
```

will calculate the byte offset associated with the subscript *i* three times. (If a, b, and c are arrays of 16-bit integers, this offset is *2*i.*) Substantial savings would be possible if this type of situation were recognized and the offset calculated only once.

An even simpler example of this is illustrated in Listing One (page 68) where the compiler produces the pair of instructions:

```
SHLD i
LHLD i
```

After execution of SHLD i, the contents of i are still in the HL register pair and the LHLD i may be omitted. Note, however, if the LHLD instruction is labeled, it may not be omitted.

Another example in Listing One is the following:

```
MOV A,H
ORA L
JNZ L1
LXI H,0
```

The zero flag is set if HL contains zero, in which case the jump to L1 is not taken and the LXI H,0 may be removed.

Simple compilation of conditionals and loops often results in multiple jump instructions that can be easily improved. A jump to a jump can be replaced by a single jump instruction, as shown in Listing One. Another commonly found construction is the jump over a jump, such as

```
    JZ  L1
    JMP L2
L1: . . .
```


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which may be replaced by

```
    JNZ  L2
L1: ...
```

Any unlabeled instruction following an unconditional jump can never be executed and may be removed. Also candidates for removal are unreachable instructions created by the jump optimization described above. For example:

```
    JMP  L1
    .
    .
    JMP  L2
L1: JMP  L3
```

After we replace JMP L1 with JMP L3 and remove the label L1, JMP L3 becomes unreachable and may also be removed. Thus, one improvement can create an opportunity for further improvement, making it worthwhile to pass the program through the optimizer more than once.

The examples so far have not involved any trade-offs between code size and execution speed. In the following situation, speed or size can be optimized, but not both. Pointer dereferencing (obtaining the value stored at a given address) may involve the following subroutine:

```
deref:  MOV A,M
        INX  H
        MOV H,M
        MOV L,A
        RET
```

Excluding the RET instruction, the above subroutine is only four bytes long. Because any program that uses pointers or arrays does quite a bit of dereferencing, use of the subroutine deref will produce a smaller program. If speed is more important, however, replacing the three-byte instruction CALL deref with four bytes of in-line code will result in faster execution. Some compilers allow the user to choose whether smaller or faster code is more important, but most compilers for microcomputers do not provide this option.

The details of the compiler and the machine instruction set may offer other opportunities for improvement. One common possibility arises from the fact that many compilers for CP/M produce 8080 code. If you have a Z80 processor, you may find ways to replace combinations of 8080 instructions with Z80 instructions. A good example is a 16-bit subtraction, which requires six instructions on an 8080 but only a single Z80 instruction. Identifying the possible improvements for your compiler will require careful study of its output and runtime library.

These examples illustrate the types of improvements that the peephole optimizer can make. Many other improvements, which require some knowledge of the organization and structure of the program such as recognizing constant expressions and removing them from loops, are beyond the scope of the optimizer presented here.

If the optimizer is specific to one compiler, it can be quite simple; see the optimization section of Small-C version 2.[3] On the other hand, if you want to use the program with different compilers or have some flexibility in what changes to make, the optimizer will require most of the capa-

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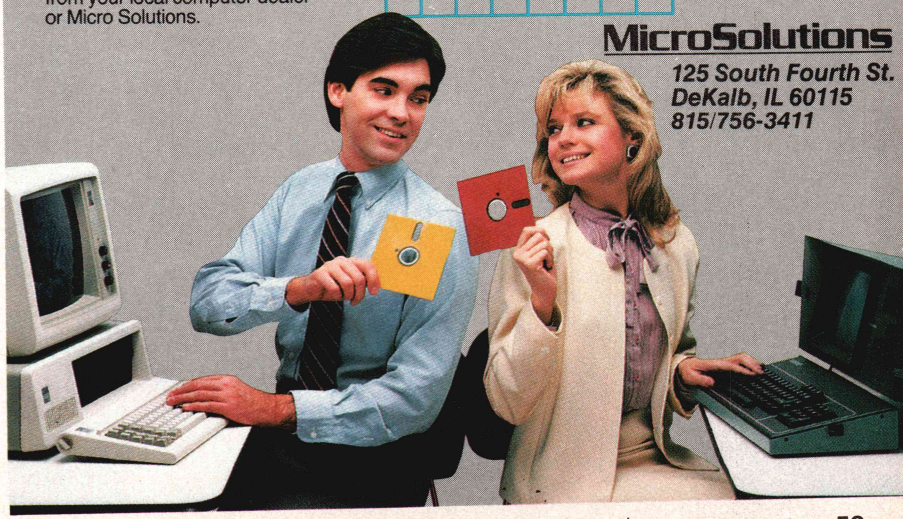

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Manx Aztec C86

"A compiler that has many strengths . . . quite valuable for serious work"

Computer Language review, February 1985

Great Code: Manx Aztec C86 generates fast executing compact code. The benchmark results below are from a study conducted by Manx. The Dhrystone benchmark (CACM 10/84 27:10 p1018) measures performance for a systems software instruction mix. The results are without register variables. With register variables, Manx, Microsoft, and Mark Williams run proportionately faster, Lattice and Computer Innovations show no improvement.

	Execution Time	Code Size	Compile/ Link Time
Dhrystone Benchmark			
Manx Aztec C86 3.3	34 secs	5,760	93 secs
Microsoft C 3.0	34 secs	7,146	119 secs
Optimized C86 2.20J	53 secs	11,009	172 secs
Mark Williams 2.0	56 secs	12,980	113 secs
Lattice 2.14	89 secs	20,404	117 secs

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Large Memory Model	Intel Object Option
Z (vi) Source Editor -c	CP/M-86 Library -c
ROM Support Package -c	INTEL HEX Utility -c
Library Source Code -c	Mixed memory models -c
MAKE, DIFF, and GREP -c	Source Debugger -c
One year of updates -c	CP/M-86 Library -c

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Debuggers	Terminal Emulator (Source)
Librarian	Clear Detailed Documentation
Source Editor	C-Stuff Library
MacRam Disk -c	UniTools (vi,make,diff,grep) -c
Library Source -c	One Year of Updates -c

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bilities of a general text editor. For that reason, I have borrowed heavily from Chapters Five and Six of Kernighan and Plauger's book *Software Tools in Pascal*,[4] which give Pascal listings for a fairly complete editor. Listing Five (page 76) contains the needed routines (translated into C and slightly extended) from Kernighan and Plauger's editor.

Regular Expressions

Once you have identified output from your compiler that may be improved, you must communicate descriptions of the improvable constructions to the optimizer program. The notation must be precise and unambiguous—capable of specifying constructions such as:

```
first line:     SHLD    (any label)
second line:    LHLD    (same label
                         as above)
```

A notation sufficiently powerful to describe such strings is used widely within the Unix environment. This notation, adopted here, is that of regular expressions.

A regular expression is a description of a set of strings. The simplest case is when the regular expression describes a single string: the regular expression is just the string itself. For example, the regular expression for the 8080 store HL instruction mnemonic is SHLD. Nonprinting characters are represented by the standard C escapes:

\b	backspace
\n	newline
\r	carriage return
\t	tab
\\	backslash
nnn	byte with octal value *nnn*

An alternative way of looking at a regular expression is as a pattern. A string matches the pattern if, starting at the left, each character of the string matches the corresponding character of the pattern. Because the optimizer is concerned with identifying lines of assembly language code, we will say that any line containing a string described by a regular expression matches that regular expression.

To specify more complex patterns, we need an element that can match more than one character in the input string. One such useful element is the wild card character (.), which will match any single character. We can also specify one of a group of characters by using a character class, which consists of a [, followed by a list of characters, and ends with a], to match a single occurrence of any of the characters enclosed in the square brackets. For example, [SL]HLD will match SHLD or LHLD.

We may use a shorthand notation for all consecutive letters or digits: [a-z] matches any lower-case letter, and [A-Z0-9] matches any upper-case letter or any digit. If the first character of the character class is ~, it negates the character class: it will match any character *except* those in the list fol-

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lowing the ~. For example, [~aA] matches any character except a or A.

Character classes are essential to matching constructions such as "any label." The standard C identifier consists of any string of letters, digits, or underscore characters that does not begin with a digit; thus, the character class that matches the first character of an identifier is [a-zA-Z_], and the remainder of the characters match the class [a-zA-Z0-9_].

To fully describe a label with a regular expression, we need a construction for "the remainder of the characters" that does not limit us to a specific number of characters. We achieve this by following any character (or character class) by an asterisk, *. The result, called a closure, will match zero or more occurrences of the single character preceding the *. For example, aa* matches any string consisting of one or more occurrences of the letter a. The regular expression describing a C identifier can now be given as:

```
[a-zA-Z_][a-zA-Z0-9_]*
```

This actually matches an identifier of unlimited length, but it serves our needs.

We now need some way of specifying "same label as above." For this, we draw on the ability to group portions of a pattern and refer to the group(s) later. A portion of a pattern that appears between the pairs of characters \(and \) constitutes a group. A group of characters matched by a parenthetical pattern may be identified by the notation \1 for the first group in the pattern, \2 for the second, up to \9 for the ninth. For example,

```
\(mat\).*\1
```

matches mathematician while

```
\(. . .\).*\1
```

matches barbarian, mathematician, and any string that repeats a group of three letters. The notation developed so far allows us to describe the example at the beginning of this section with two regular expressions:

```
SHLD\t\([a-zA-Z_]
  [a-zA-Z0-9_]*\)
LHLD\t\1
```

Finally, it is sometimes useful to require that the string matching a regular expression occur at the beginning or end of a line. The characters to do this are ^ for the beginning of a line and $ for the end of a line. Thus, ^A matches any line that begins with A, and ^$ matches only empty lines. Any characters that have special meanings (e.g., [ ]*.\^$~-) may have the special meaning turned off by preceding the special character with \. The pattern \.$ matches any line that ends with a period.

This flexible and powerful notation suffices to describe most constructions appropriate for improvement with a peephole optimizer. There are a few traps for the unwary, especially when using closures. Remember that x* matches zero or more occurrences of x, so that the regular expression x* matches any line, even those with no x's at all. When you want to match one or more x's, use xx*. Another point is that any closure matches the

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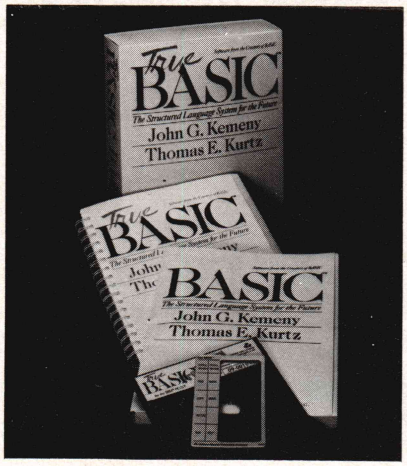

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longest possible string: e.*e matches the entire word *emergence,* not just *eme* or *erge.* Table 1 (below) gives some more examples of regular expressions and the strings they describe. For a more extensive discussion of regular expressions, see Chapter 3 of Aho and Ullman's *Principles of Compiler Design.*[5]

Using the Optimizer

The description of each improvement in the compiler output has two parts: a list of regular expressions describing the code to be replaced and a list of lines of improved assembly language code. A group of lines is replaced only if each line in turn matches the corresponding regular expression. The constructions \1, \2, and so on in a replacement cause the replacement to contain the same string matched by the corresponding "\(\)" group in the list of regular expressions.

The list of potential improvements is placed in a file that is read by the optimizer. Listing Six (page 82) shows such a file for use with C/80 compiler output. Each improvement consists of the following: one or more lines containing regular expressions identifying the construction that may be improved, a separator line that contains a % as its first character, zero or more lines that are to replace the text matched by the regular expressions, and a terminator line starting with %%. The file may contain any number of potential improvements. In Listing Six, comments describe each improvement; they make the output somewhat larger than the input and may be removed if desired.

The program command line syntax is

opt options infile outfile

where infile is the name of the file containing the assembly language source code to be optimized, outfile is the name of the file to contain the optimized output (must be different from infile), and options represents zero or more of the following optional parameters:

- -b*n* Store *n* lines in the internal FIFO buffer. Default is 500.
- -f*file* Read the list of improvements from *file.* Default is opt.dat.
- -j*re* A jump instruction described by the regular expression *re.* Default is \tJ[CEMNOPZ]*\t.
- -l*re* A label described by the regular expression *re.* Default is [a-zA-Z_\.][a-zA-Z_0-9]*.
- -o Omit jump optimization. With this option selected, the optimizer can be used as a general purpose stream editor.
- -u*re* An unconditional jump instruction described by the regular expression *re.* Default is \tJMP\t.
- -v Turn off verbose output. Normally opt displays the last line of every improvable construction on the console; selecting this option omits that output.

^. . .$	Matches any line with exactly three characters
(.*)	Matches any string enclosed in parentheses
/ *[a-zA-Z]**/	Matches any C comment containing only blanks and letters
[~]*	Matches any string of nonblank characters
\([a-z][a-z]*\)\tJMP\t\1	Matches "loop JMP loop" but not "loop1 JMP loop" or "abc JMP xyz"
\(..*\)\1	Matches any string containing two adjacent repeated substrings such as *beriberi, vacuum,* and *tintinnabulation*
\(..*\)\(..*\)\2\1	Matches *affair, accommodate,* and *this is the end* (\1="th", \2="is ")

Table 1
Examples of Regular Expressions and Matching Strings

ROUTINE	CALLS	TICKS	% TIME (Approx.)
amatch	81309	9370	27
omatch	92501	6548	19
fgets	3149	3707	11
outline	3103	3541	10
match	32504	3011	9
locate	36934	2504	7
patsize	42331	2331	7
findsym	1316	1363	4
strcmp	34942	812	2
free	3374	654	2
optimiz	3103	376	1
malloc	3692	287	1
main	1	112	0

Table 2
Profiler Output for Optimizing a Test File

The internal organization of the program is quite simple. Each line is read into a FIFO buffer in memory. The size of this buffer determines the range of jump instructions that may be optimized. The input is compared with the regular expressions of the improvable constructions, which are contained in a linked list. If a match is found, the appropriate replacement is made. A symbol table containing all the labels in the input is maintained for jump optimization.

Because this article is on optimization, it is appropriate to discuss the optimization of the optimizer. As given in Listings Two to Six (pages 68–83), the program processes approximately

200 lines per minute. Using the optimizer on its own assembly language code saved 199 bytes and increased speed by about 2%. Adding to the data file some constructions specific to the optimizer and reoptimizing saved an additional 86 bytes and increased speed by another 1%, for a total improvement of 285 bytes and about 3%. A third run, made with a data file that replaced calls to the pointer dereferencing routine with inline code, increased program size by 473 bytes and speed by 10%.

We might wish to improve two separate aspects of the peephole optimizer's performance. First, consider the amount of improvement the optimizer makes in the programs it processes. We could increase performance in this area by finding more improvable constructions in the compiler output and adding them to the data file opt.dat. Unless we have missed some extremely poor and very common compiler output, however, this approach will likely produce only a small increase in performance. As is usually the case, substantial improvement requires the use of an improved algorithm.

Second, consider the speed of the optimizer in accomplishing its task—presently about 200 lines per minute. Once again, small improvements may be made by tweaking the present code, but major improvements will require a change to better algorithms. By using the profiler included in the Software Toolworks' C/80 package, we can identify those subroutines of the program that are executed most frequently. The profiler output for a run of the optimizer is shown in Table 2 (page 66).

Table 2 shows that the optimizer spends over two-thirds of its time matching regular expressions to strings (match( ) and subsidiary routines). Clearly, any significant increase in speed will require an improvement in the pattern-matching code. I have made a small effort along these lines by replacing the C version of the routine locate( ) with an assembly language version. Because better algorithms for regular expression matching are known, this seems like the most profitable course for increasing the speed of the program. In contrast, replacing the linearly searched linked list used for the symbol table with a more efficient hash table cannot increase the speed of the program by more than 4% because only 4% of the execution time is spent in the routine findsym( ) looking up symbols in the table.

Installation

Although I have endeavored to make the program as flexible as possible so it will be useful with a variety of compilers, I have tested it only with the C/80 compiler. Users of other compilers will have to construct a data file like that in Listing Six for the constructions peculiar to their compiler.

Listings Two to Five are "standard" C and should be portable to other C compilers. My library follows the usage of the Unix (version 7) library and differs only slightly from the library distributed with C/80 and some other C compilers. Listing Seven (page 83) shows the library functions used by the optimizer.

Although I have not tested it, the new Small-C library[6] appears to contain suitable routines, with the exception of the memory management routines malloc( ) and free( ). The optimizer frees blocks of memory without regard to the order in which

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they were allocated. The C/80 library (version 3) also contains suitable routines, provided that the error return value is changed to 0 (NULL) from -1. Listings for suitable memory management routines are also given in Chapter 8 of Kernighan and Ritchie.[7]

Availability

I will return a copy of the source code and an executable .COM file (for CP/M 2.x) to anyone who sends me a postage-paid disk mailer, a formatted 5¼-inch disk, and $10.00. I can write a large number of single-sided, soft-sectored formats but do not have the hardware for hard-sectored or 8-inch disks.

References

[1]D. E. Cortesi. *Dr. Dobb's Journal.* No. 83 (November 1983) p. 10, No. 87 (January 1984) p. 18, and No. 91 (May 1984) p. 12.

[2]Jim Gilbreath and Gary Gilbreath. *Byte.* (January 1983) p. 283.

[3]J. E. Hendrix. *Dr. Dobb's Journal.* No. 74 (December 1982) p. 16, and No. 75 (January 1983) p. 48.

[4]Brian W. Kernighan and P. J. Plauger. *Software Tools in Pascal.* Addison-Wesley, 1981. See also Brian W. Kernighan and P. J. Plauger's *Software Tools* (Addison-Wesley, 1976), which gives the same tools in Ratfor, a Fortran-based language.

[5]Alfred V. Aho and Jeffrey D. Ullman. *Principles of Compiler Design.* Addison-Wesley, 1979.

[6]James Hendrix and Ernest Payne. *Dr. Dobb's Journal.* No. 91 (May 1984) p. 50, and No. 92 (June 1984) p. 56.

[7]Brian W. Kernighan and Dennis M. Ritchie. *The C Programming Language.* Prentice-Hall, 1978.

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Peephole Optimizer

(Text begins on page 56)

Listing One

```
int i,j,m,n;
while (i == 0)
{       i = j + n;
        m = i + j;
        if (j == 1)
                j = 0;
}
```

(a) Fragment of C code

```
                        ; start of loop
.f:     LHLD    i       ; evaluate i == 0
        MOV     A,H
        ORA     L
        JNZ     .g      ; jump out of loop if not true
        LHLD    j       ; i = j + n
        XCHG
        LHLD    n
        DAD     D
        SHLD    i
        LHLD    i       ; m = i + j
        XCHG
        LHLD    j
        DAD     D
        SHLD    m
        LHLD    j       ; evaluate j == 1
        DCX     H
        MOV     A,H
        ORA     L
        JNZ     .h      ; jump if not true
        LXI     H,0     ; j = 0
        SHLD    j
.h:     JMP     .f      ; loop
.g:     DS      0       ; continue with rest of program
```

(b) Assembly language compiler output
(Comments added)

```
                        ; start of loop
.f:     LHLD    i       ; evaluate i == 0
        MOV     A,H
        ORA     L
        JNZ     .g      ; jump out of loop if not true
        LHLD    j       ; i = j + n
        XCHG
        LHLD    n
        DAD     D
        SHLD    i       ; redundant LHLD deleted
        XCHG
        LHLD    j
        DAD     D
        SHLD    m
        LHLD    j       ; evaluate j == 1
        DCX     H
        MOV     A,H
        ORA     L
        JNZ     .f      ; JNZ to JMP improved
                        ; LXI H,0 removed following in line test
        SHLD    j
        JMP     .f
.g:     DS      0       ; continue with rest of program
```

(c) Optimized assembly language code

End Listing One

Listing Two

```
/* optdefs.h -- Definitions and declarations for peephole optimizer. */

/****************************************
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****************************************/

/* Standard definitions (stdio.h) */

#define EOF     -1
#define NULL    0
#define TRUE    1
#define FALSE   0
#define MAXSTR  256     /* Maximum string length */
#define FILE    int     /* File descriptor type */

/* Definitions for optimizer */

#define MAXLINES        500     /* Lines of source in memory  */
#define JTSIZE          10      /* Entries in jump list table */
#define LBLLEN          15      /* Maximum label length */
#define OPTIONS         "B:F:J:L:UU:V"  /* Legal options */
#define LBLTERM         ':'     /* Character which terminates a label */
#define SYMLEN          8       /* Symbol (label) length */
```

```
#define UNDEF           0       /* Undefined symbol */
#define INBUF           1       /* Symbol defined and in buffer */
#define OUTBUF          2       /* Symbol written to output, removed from
                                   buffer */
#define UNJMPD          3       /* Symbol is label of JMP, replaced with
                                   destination */

/* Structure declarations */

struct lkline {         /* Linked list of lines */
        struct lkline *nextln;  /* Link to next line */
        char *ln;               /* This line */
};

struct trfmn {          /* Transformation from old to new code */
        int nold;       /* Number of lines in old construction */
        int nnew;       /* Number of lines in new construction */
        struct lkline *old;     /* Linked list of old reg. exprs. */
        struct lkline *new;     /* Linked list of new substitutions */
        struct trfmn *nexttr;   /* Link to next transformation */
};

struct jmp_lst {        /* List of lines with jumps to a label */
        int njmp;
        int jlines[JTSIZE];     /* Line nos. containing jump to label */
        struct jmp_lst *jlnext;
};

struct symt {           /* Symbol table entry */
        char sname[SYMLEN+1];
        int lineno;             /* Line number in buffer */
        char scode;             /* Status: undefined, in buffer,
                                   written out, replaced */
        struct jmp_lst *jmplst;
        struct symt *snext;
};

/* Definitions for regular expression code */

#define MAXPAT  (2*MAXSTR)
#define CLOSIZE 1       /* Size of a closure entry */
#define CLOSURE '*'
#define BOL     '^'
#define BOLSTR  "^"     /* String consisting of BOL */
#define EOL     '$'
#define ANY     '.'
#define CCL     '['
#define CCLEND  ']'
#define NEGATE  '~'
#define NCCL    '!'     /* Cannot be the same as NEGATE. */
#define LITCHAR 'c'

#define ENDSTR  '\0'
#define NEWLINE '\n'
#define ESCAPE  '\\'
#define DASH    '-'

#define GRPST   '('     /* Codes for grouping and subpatterns */
#define GRPEND  ')'
#define GRPPAT  '#'
#define DITTO   -1

/* #define      Z80             /* Insert this define if you have
                                   a Z80 processor. */
```

End Listing Two

Listing Three

```
/* optglob.c -- Global variable declarations for optimizer. */

/*****************************************
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*****************************************/

char **linep;           /* Array of pointers to lines */
int nlines = 0;         /* Number of lines */
int frstln;             /* Index of oldest line in buffer */
int curln;              /* Current line in buffer */
FILE infd;              /* Input file descriptor */
FILE outfd;             /* Output file descriptor */
unsigned maxlines =     /* Lines in buffer */
        MAXLINES;
int verbose = TRUE;     /* Verbose output flag */
int jmpopt = TRUE;      /* Flag for jump optimization */
int optind = 0;         /* Index of next argument */
char *optarg;           /* Pointer to option argument */
struct trfmn *trans;

char *patfile = "opt.dat\0\0\0\0\0\0\0";        /* File for optimization
                                                   data */
char *lbl = "[a-zA-Z_\.][a-zA-Z0-9_]*";         /* Label template */
char *jmpins = "\tJ[CEMNOPZ]*\t";               /* Jump instruction
                                                   template */
char *ucjmp = "\tJMP\t";                /* Unconditional jump */

char *lblpat, *jmppat, *ucjpat;         /* Pointers to patterns made
                                           from reg. expr. */

struct symt frstsym = {
        ('\0'),         /* sname */
        -1,             /* lineno */
```

(Continued on next page)

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Peephole Optimizer (Listing continued, text begins on page 56)

Listing Three

```
        0,              /* scode */
        NULL,           /* jmplst */
        NULL};          /* snext */

struct sym *symtab = &frstsym;          /* Start of symbol table */

/* Global variable declarations for regular expression code */

char pat[MAXPAT];       /* Space for pattern */
int lparen, rparen;     /* Parenthesis counts */
char *gstart[10];       /* Pointers to start of grouped text */
char *gend[10];         /* Pointers to end of grouped text */
char *lgp;              /* Pointer to start of last group */
```

End Listing Three

Listing Four

```
/*  opt.c -- Assembly language optimizer */

/****************************************
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/*
Performs peephole and jump optimization of an assembly language
source file.  Transformations for peephole optimizer are specified
in file opt.dat as follows:

        regular expressions
        for matched lines
        %
        replacement lines
        %%

Command line syntax is

opt [ -bnn -ffile -o -lre -jre -ure -v ] infile outfile

where the options are

-bnn    Use nn lines in the FIFO buffer (default=1000).
-ffile  Read peephole optimization information from file instead
        of opt.dat.
-o      Do not do jump optimization.
-lre    Labels defined by regular expression re.
-jre    Jump instructions defined by regular expression re.
-ure    Unconditional jump instruction defined by regular
        expression re.
-v      Verbose output off.
*/


#include        "b:optdefs.h"
#include        "b:optglob.c"
#include        "b:restuf.c"

/* Main program */

main(argc, argv)
int argc;
char **argv;
{
char inline[MAXSTR], *s, *lines;
int c, i;
char *p, *q;
FILE patfd;
char *fgets(), *newline(), *makepat(), *strcpy();
struct sym *symp, *chksym();

/* Initialization */
```


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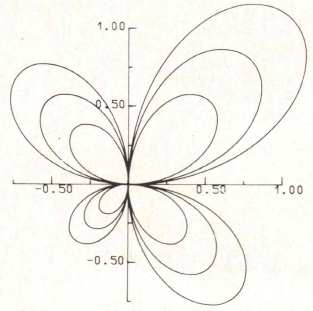

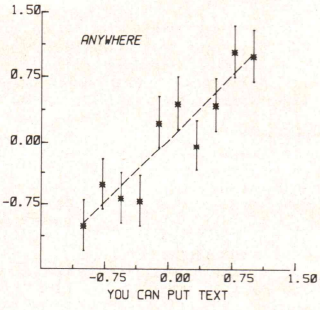

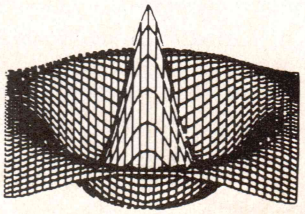

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```
frstln = 0;
curln = maxlines - 1;

/* Create patterns for jumps and labels from regular expressions */
/* Allocate memory. */
if ((lblpat = sbrk(MAXSTR)) == -1 ||
    (jmppat = sbrk(MAXSTR)) == -1 ||
    (ucjpat = sbrk(MAXSTR)) == -1)
        error("Not enough memory");

/* Create patterns. */
p = lblpat;
makepat(lbl, '\0', lblpat, &p);
p = jmppat;
makepat(jmpins, '\0', jmppat, &p);
p = ucjpat;
makepat(ucjmp, '\0', ucjpat, &p);

/* Allocate memory for groups. */
for (i = 1; i < 10; ++i)
        gstart[i] = sbrk(MAXSTR);
if (gstart[10] == -1)
        error("Not enough memory");

/* Process options. */
while ((c = getopt(argc, argv, OPTIONS)) != EOF)
{       switch(c | 0x20) {
        case 'b':       /* Set FIFO buffer size. */
                maxlines = atoi(optarg);
                break;
        case 'f':       /* Set data file name. */
                strcpy(patfile, optarg);
                break;
        case 'l':       /* R.e. for labels */
                p = lblpat;
                makepat(optarg, '\0', lblpat, &p);
                break;
        case 'j':       /* R.e. for jumps */
                p = jmppat;
                makepat(optarg, '\0', jmppat, &p);
                break;
        case 'o':       /* Omit jump optimization. */
                jmpopt = !jmpopt;
                break;
        case 'u':       /* R.e. for unconditional jumps */
                p = ucjpat;
                makepat(optarg, '\0', ucjpat, &p);
                break;
        case 'v':       /* Switch verbose output. */
                verbose = !verbose;
                break;
        default:
                error("usage: opt [ -bnn -ffile -lre -jre -ure -v ]\
 [ infile [ outfile ] ]");
        }
}

/* Read optimization data file. */
patfd = mustopen(patfile, "r");
gettmpl(patfd);
fclose(patfd);

/* Allocate memory for FIFO buffer. */
if ((linep = sbrk(maxlines*sizeof(char *))) == -1)
        error("Not enough memory");

/* Set up i/o channels. */
outfd = stdout;
infd = stdin;
if (argc > optind)
{       infd = mustopen(argv[optind++], "r");
        if (argc > optind)
                outfd = mustopen(argv[optind++], "w");
}

/* Main loop */
while ((s = fgets(inline, MAXSTR, infd)) != NULL)
{       newline(s);
        /* Update symbol table. */
        if(jmpopt && (symp = chksym(curln)) != NULL)
                unjump(symp);   /* Remove jumps to JMP. */
        /* Optimize current line. */
        optimize(curln);
}
fclose(infd);

/* Output contents of FIFO buffer. */
while (frstln != curln)
        outline();
outline();
if (outfd != 0)
        fclose(outfd);
}

/* newline -- Add a line to buffer, output some old ones to make space
              if needed.  Update frstln, curln, and nlines.
*/

char *
newline(str)
char *str;
{
char *s, *strcpy(), *malloc();

/* Check for buffer wrap around. */
if (++curln >= maxlines) {
        curln = 0;
}
while (nlines >= maxlines || (s = malloc(strlen(str)+1)) == NULL)
{       /* Make some space */
        outline();
}
++nlines;
return(linep[curln] = strcpy(s, str));
}

/* optimize -- Look for improvable code and make improvements */

optimize(ln)
int ln;
{
struct trfmn *p;
int n, m;
char *s;
struct lkline *o;

/* Loop through all possible transformations. */
for (p = trans; p->nexttr != NULL; p = p->nexttr) {
        /* Check lines in buffer against r.e. in transformation. */
        lparen = rparen = 0;
        for (n = p->nold, o = p->old;
           n > 0 && match(linep[(m=ln-n+1) >= 0 ? m : m+maxlines],
           o->ln); --n) {
                o = o->nextln;
```

(Continued on next page)

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Peephole Optimizer (Listing continued, text begins on page 56)

Listing Four

```
        }
        if (n > 0)      /* No match, skip to next transformation. */
                continue;
        if (verbose)    /* Print last line matched. */
                fprintf(stderr, "MATCH---%s", linep[ln]);
        /* Replace matched lines with improved code. */
        if (!subst(ln,p))
                error("substitute failed");
}
}

/* unjump -- Route jumps to jumps directly to target */
/*      syp is pointer to symbol table entry for label on JMP */
unjump(syp)
struct symt *syp;
{
char *p, dpat[MAXSTR];
int i, errflg;
struct symt *dsyp, *isjmp();
struct jmp_lst *jp;

if (syp->scode == OUTBUF) {
        /* Target is not in memory. */

        fprintf(stderr, "%s not in buffer\n", syp->sname);
        for (jp = syp->jmplst; jp != NULL; jp = jp->jlnext)
                free(jp);       /* Release memory used by jump list. */
        errflg = TRUE;
}
else {  /* Target is in memory. */
        errflg = FALSE;
        if ((dsyp = isjmp(linep[syp->lineno])) == NULL)
        {       message(linep[syp->lineno]);
                error("Not a jump");    /* "Can't happen." */
        }

        /* Make literal pattern for substitutions */
        for (p=syp->sname, i=0; *p != '\0'; ++p)
        {       dpat[i++] = LITCHAR;
                dpat[i++] = *p;
        }
        dpat[i++] = CLOSURE;
        dpat[i++] = LITCHAR;
        dpat[i++] = LBLTERM;
        dpat[i] = '\0';
        /* Replace destination label for every entry in jump list. */
        jp = syp->jmplst;
        for (jp = syp->jmplst; jp != NULL && jp->njmp >= 0; jp = jp->jlnext)
        {       for (i=0; i < jp->njmp; ++i)
                {       if (!subline(jp->jlines[i], dpat, dsyp->sname))
                        {       errflg = TRUE;
                                fprintf(stderr,
                                   "Cannot substitute %s in %s\n",
                                   dsyp->sname, linep[jp->jlines[i]]);
                        }
                        /* Add new reference to jump list */
                        addjmp(dsyp->sname, jp->jlines[i]);
                }
                free(jp);
        }
}
syp->jmplst = NULL;
if (!errflg)    /* Delete label from target. */
{       if (!subline(syp->lineno, dpat, ""))
                fprintf(stderr,
                   "Failed to delete %s in %s\n",
                   dpat, linep[syp->lineno]);
        syp->scode = UNJMPD;
}
}

/* I/O routines for optimizer */

/* outline -- Output a line from FIFO buffer. */

outline()
{
struct symt *s, *islab(), *isjmp();
struct jmp_lst *jp;

if (linep[frstln] != NULL) {    /* If line not deleted */
        fputs(linep[frstln], outfd);
        /* Check for labels and jumps. */
        if ((s = islab(linep[frstln])) != NULL)
                s->scode = OUTBUF;
        if ((s = isjmp(linep[frstln])) != NULL)
        {       s->scode = OUTBUF;
                /* Delete jump list. */
                for (jp=s->jmplst; jp != NULL; jp = jp->jlnext)
                        free(jp);
                s->jmplst = NULL;
        }
        --nlines;
        free(linep[frstln]);
}
/* Check for buffer wrap around. */
if (++frstln >= maxlines) {
        frstln = 0;
}
}

/* gettmpl -- Get templates for changes. */

gettmpl(fd)
FILE fd;
{
int n;
struct trfmn *t;
struct lkline *l, **ll, *mm, *newlk();
char line[MAXSTR], *s, *p;
char *fgets(), *makepat(), *makesub(), *strcpy();

/* Allocate memory for first transformation. */
t = trans = (struct trfmn *) sbrk(sizeof(struct trfmn));
t->nexttr = NULL;

while ((s = fgets(line, MAXSTR, fd)) != NULL)
{       lparen = rparen = 0;    /* Initialize parenthesis counters. */
        ll = &t->old;
        t->nold = t->nnew = 0;
        while (*s != '%' && s != NULL)
        {       p = pat;
                if (makepat(s, '\n', pat, &p) == NULL)
                {       message(line);
                        error ("bad r.e.");
                }
                l = newlk(ll, pat);
                ll = &l->nextln;
                ++t->nold;      /* Increment line count. */
                s = fgets(line, MAXSTR, fd);
        }
        if (s != NULL && strncmp(s, "%%", 2) != 0)
        {       mm = &t->new;
                while ((s = fgets(line, MAXSTR, fd)) != NULL &&

                   strncmp(s, "%%", 2) != 0) {
                        /* Get replacement strings. */
                        if (makesub(line, '\n', pat) == NULL)
                        {       message(line);
                                error("bad sub string");
                        }
                        l = newlk(mm, pat);
                        mm = &l->nextln;
                        ++t->nnew;
                }
        }
        /* Allocate memory for next transformation. */
        t->nexttr = (struct trfmn *) sbrk(sizeof(struct trfmn));
        t = t->nexttr;
        t->nexttr = NULL;
}
}

/* newlk -- Create a new lkline structure. */

struct lkline *
newlk(lkp, str)
struct lkline **lkp;    /* Address of pointer to next member of
   linked list. */
char *str;
{
char *strcpy();
struct lkline *l;

if ((l = (struct lkline *)sbrk(sizeof(struct lkline))) == NULL)
        error("memory full");
*lkp = l;
if ((l->ln = sbrk(strlen(str)+1)) == NULL)
        error("memory full");
strcpy(l->ln, str);
l->nextln = NULL;
return(l);
}

/* sttecpy -- Copy string between start and end pointers. */
char *
sttecpy(dest, start, end)
char *dest, *start, *end;
{
char *p;

for (p = dest; start < end; )
        *p++ = *start++;
*p = '\0';
return(dest);
}

/*****************************************/
/* Symbol table routines for optimizer. */
/* addsym -- Add a label to the symbol table. */

struct symt *
addsym(name)
char *name;
{
char *p, *q, *strcpy();
static struct symt *s = &frstsym, *sret;

strcpy(s->sname, name);
```

(Continued on page 74)

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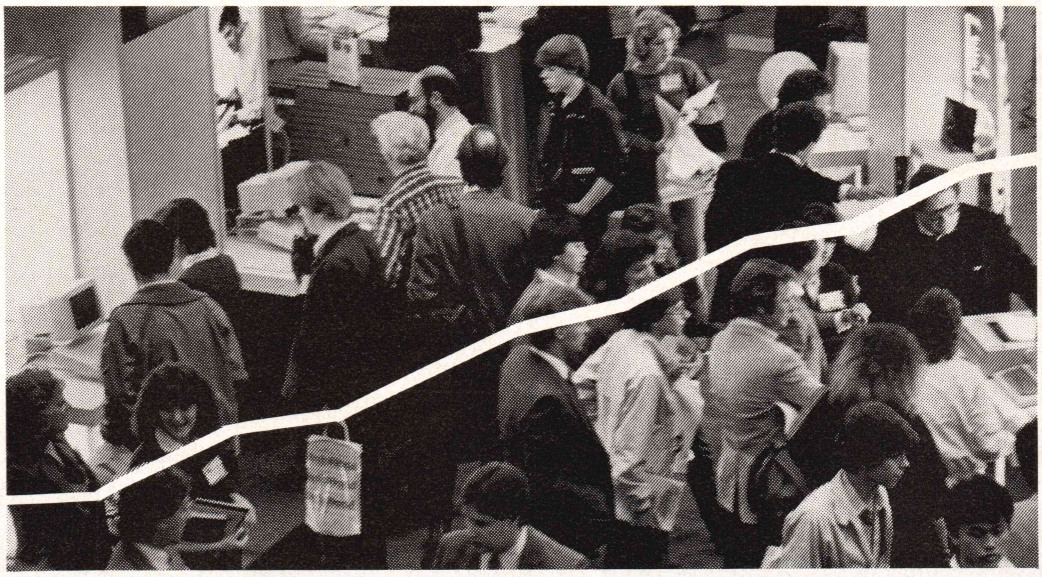

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Peephole Optimizer (Listing continued, text begins on page 56)

Listing Four

```
s->lineno = -1;
s->scode = INBUF;
if ((s->snext = malloc(sizeof(struct symt))) == NULL)
        error("symbol table overflow");
sret = s;
s = s->snext;
s->snext = NULL;
s->jmplst = NULL;
return(sret);
}

/* addjmp -- Add line number to list of jumps to label. */

addjmp(name, lineno)
char *name;
int lineno;
{
char *p, *q;
struct symt *symp, *findsym(), *addsym();
int n;
struct jmp_lst **jp;

if ((symp = findsym(name)) == NULL)
{       symp = addsym(name);    /* Symbol not found, add it to table. */
        symp->scode = UNDEF;
}
jp = &symp->jmplst;
/* skip to end of jump list */
while (*jp != NULL && (*jp)->njmp >= JTSIZE)
        jp = &(*jp)->jlnext;    /* Skip to last block of jump list. */
if (*jp == NULL)        /* Allocate space for new block. */
{       if ((*jp = malloc(sizeof(struct jmp_lst))) == NULL)
                error("jump list overflow");
        else    /* Initialize new block. */
        {       (*jp)->njmp = 0;
                (*jp)->jlnext = NULL;
        }
}
(*jp)->jlines[(*jp)->njmp++] = lineno;
}

/* findsym -- Linear search of symbol table. */

struct symt *
findsym(name)

char *name;
{
struct symt *s;

for (s = &frstsym; s->snext != NULL; s = s->snext)
        if (strcmp(s->sname, name) == 0)
                return(s);
return(NULL);
}

/* chksym -- Check for a labeled line or line with a jump. */

struct symt *
chksym(curln)
int curln;
{
char *sttecpy();
struct symt *syp, *s,  *addsym(), *islab(), *isjmp();

        if (syp = islab(linep[curln]))
                syp->lineno = curln;
        if (syp->lineno = -1)   /* First time for this line. */
                syp->lineno = curln;
        if ((s = isjmp(linep[curln])) != NULL)
                addjmp(s->sname, curln);
        if (syp != NULL)
        {       if (match(linep[curln], ucjpat) != NULL)
                        return(syp);    /* Labeled unconditional jump. */
        }
        return(NULL);
}

/* islab -- If str points to a valid label return pointer to its
            entry in symbol table, else return NULL. */

struct symt *
islab(str)
char *str;
{
```


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```
char *p, *q, name[LBLLEN], *amatch(), *sttecpy();
struct symt *syp, *addsym();

p = lblpat;
if ((q = amatch(str, str, &p)) != NULL) {
        if((syp = findsym(sttecpy(name, str, q))) == NULL) {
                        syp = addsym(name);
                }
        }
return(syp);
}

/* isjmp -- If line contains a jump instruction
        return pointer to its destination label symbol table entry
        otherwise return NULL. */
struct symt *
isjmp(line)
char *line;
{
char *p, *q, *r, name[LBLLEN];
struct symt *syp, *findsym();
char *amatch(), *sttecpy();

syp = NULL;
if ((p = match(line, jmppat)) != NULL) {
        q = lblpat;
        if ((r = amatch(p,p,&q)) != NULL) {
                sttecpy(name, p, r);
                if ((syp = findsym(name)) == NULL)
                        syp = addsym(name);
        }
}
return(syp);
}

/**********************************/
/* Utility routines */

/* getopt -- Unpack options from arg list. */
/*       Argc and argv are argument count, and values from main.
        Optstr is a string of legal option letters.
        Getopt returns the next option letter from argv.
        If the letter in optstr is followed by ':' the external
                pointer optarg is set to point to the argument
                following the option letter.
        The external variable optind is set to the index of the
                next argument in the argv array to be processed.
        If an illegal option is found, getopt returns '?'
        If the next argument in argv is not an option
                getopt returns EOF
*/

getopt(argc, argv, optstr)
int argc;
char *argv[], *optstr;
{
static char *cp;
char *p;
char *strchr();

if(optind == 0)
        cp = argv[++optind] + 1;        /* First call */
if(*argv[optind] != '-' || optind >= argc)
        return(EOF);            /* No more options */
if(*cp == '-')
{       ++optind;
        return(EOF);            /* End of options */
}
if((p = strchr(optstr, *cp++)) == NULL)
{       fputs("unknown option: ", stderr);

        putc(*(cp-1), stderr);
        putc('\n', stderr);
        if(*cp == '\0')
                cp = argv[++optind] + 1;
        return('?');
}
if(*(p+1) == ':')
{       if(*cp == '\0')         /* Get argument */
                optarg = argv[++optind];
        else
                optarg = cp;
        cp = argv[++optind] + 1;
}
else
        if(*cp == '\0')
                cp = argv[++optind] + 1;        /* Set up for
                                                   next argv. */
return(*p);
}

/* message -- Send a message to the console (stderr) and return. */
message(s)
char *s();
{
fputs(s, stderr);
putc('\n', stderr);
return(0);
}
```

(Continued on next page)

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Peephole Optimizer (Listing continued, text begins on page 56)

Listing Four

```
/* mustopen -- Attempt to open a file, exit on failure. */

FILE
mustopen(name, mode)
char *name, *mode;
{
FILE fd;
if((fd = fopen(name, mode)) == NULL)
{       fputs(name, stderr);
        error(": cannot open file");
}
return(fd);
}

/* message -- Send a message to the console (stderr) and exit. */
error(s)
char *s;
{
fputs(s, stderr);
putc('\n', stderr);
fclose(stderr);
exit();
}
```

End Listing Four

Listing Five

```
/* restuf.c -- Regular expression routines. */

/* These routines are translations into C of the regular expression
*       matching and pattern generation routines in
*       B.W. Kernighan and P.J. Plauger, "Software Tools in Pascal"
*       chapters 5 and 6.
*   The major extension is the addition of code to allow matching and
*       substitution of parts of expressions using \(...\) for
*       grouping and \n for replacement.
*/

/* match -- Find match anywhere on line. */

match(lin, pat)
char *lin, *pat;
char *amatch();
{
char *pos, *lst, *p;

lst = lin;
for (pos = NULL; *lin != ENDSTR && pos == NULL; ++lin)
{       p = pat;
        pos = amatch(lst, lin, &p);
}
return(pos);
}

/* amatch -- Anchored match */
/* Look for match between lin and pat. */
/* Return pointer to next unmatched character in line,
   or NULL if no match. */
/* lst is pointer to start of line. */
/* lin is pointer to current position in line. */
/* *ppat is pointer to current position in pattern,
   updated if match found. */

char *
amatch(lst, lin, ppat)
char *lst, *lin, **ppat;
{
auto char *lp, *mp, *tp;
auto int level, skip;
char tpat[MAXPAT];
char *strcpy();

while (**ppat != ENDSTR)
{       switch(**ppat) {
        case CLOSURE: {
                *ppat += patsize(*ppat);        /* Step over closure. */
                for (lp = lin; *lp != ENDSTR; )
                        if (! omatch(lst, &lp, *ppat))
                                break;
                if (*(tp = *ppat + patsize(*ppat)) == GRPEND)


        {       skip = patsize(tp);     /* At end of group, skip
                                           over group closure. */
        }
        else
                skip = 0;
        /* lp points to input character that made us fail. */
        /* Match rest of pattern against rest of input. */
        /* Shrink closure by 1 after each failure. */
        while (lp >= lin)
        {       tp = *ppat + patsize(*ppat) + skip;
                if (skip)
                        gend[lparen] = gstart[lparen] +
                           (int)(lp - lgp);
                if ((mp = amatch(lst, lp, &tp)) != NULL)
                        if (skip == 0)
                        {       *ppat = tp;
                                return(mp);
                        }
                        else
                        {       *ppat += patsize(*ppat) + skip;
                                return(lp);
                        }
                else
                        lp--;
        }
        return(NULL);
        /* If mp == NULL failure, else success. */
}
case GRPST: {   /* Start of group */
        mp = *ppat;
        *ppat += patsize(*ppat);
        level = ++lparen;
        strcpy(qstart[level], lin);
        lgp = lin;
        if ((lin = amatch(lst, lin, ppat)) == NULL)
        {       *ppat = mp;
                --lparen;
                return(NULL);
        }
        qend[level] = qstart[level] + (int)(lin - lgp);
        break;
}
case GRPEND: {  /* End of group */
        *ppat += patsize(*ppat);
        ++rparen;
        return(lin);
}
case GRPPAT: {  /* Match previously found group. */
        if ((level = (*ppat)[1] - '0') < 1 || level > 9)
        {       message(*ppat);
                error(" amatch: can't happen");
        }
        *ppat += patsize(*ppat);
        if (gend[level] > gstart[level] + MAXSTR/2)
                return(NULL);   /* Group is too long for tpat. */

                /* Make temporary pattern from matched group. */
                for (tp = tpat, lp = gstart[level]; lp < gend[level]; )
                {       *tp++ = LITCHAR;
                        *tp++ = *lp++;
                }
                *tp = ENDSTR;
                tp = tpat;
                if((lin = amatch(lst, lin, &tp)) == NULL)
                        return(NULL);
                break;
        }
        default:
        if (omatch(lst, &lin, *ppat))
        {       *ppat += patsize(*ppat);
        }
        else {
                return(NULL);
        }
}
}
return(lin);
}

/* omatch -- Match one pattern element at pat. */

omatch(lin, linp, pat)
char *lin, **linp, *pat;
{
char *lpos;
int advance;

advance = -1;
lpos = *linp;

if (*lpos == ENDSTR)
        return(FALSE);
switch(*pat)
{
case LITCHAR:
        if (*lpos == pat[1])
                advance = 1;
        break;
case BOL:
        if (lpos == lin)
                advance = 0;
        break;
case ANY:
        if (*lpos != NEWLINE)
                advance = 1;
        break;
case EOL:
        if (*lpos == NEWLINE)
                advance = 0;
        break;
case CCL:
```

(Continued on page 78)

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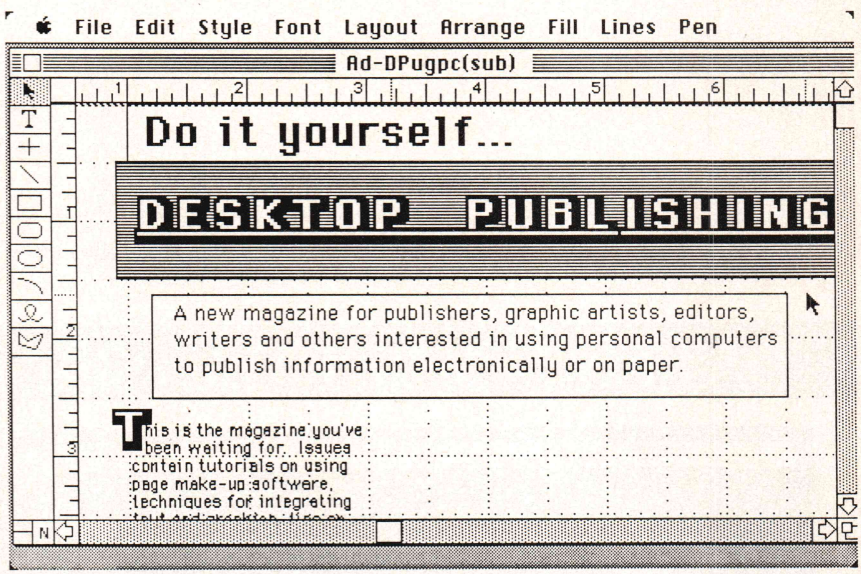

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Peephole Optimizer

(Listing continued, text begins on page 56)

Listing Five

```
        if (locate(*lpos, &(pat[1])))
                advance = 1;
        break;
case NCCL:
        if (*lpos != NEWLINE && ! locate(*lpos, &(pat[1])))
                advance = 1;
        break;
default:
        message(pat);
        error("in omatch: can't happen");
}
if (advance >= 0)
{       *linp += advance;
        return(TRUE);
}
else
        return(FALSE);
}

/* patsize -- Returns size of pattern entry at pat. */

patsize(pat)
char *pat;
{
switch (*pat)
{
case LITCHAR:
case GRPPAT:
        return(2);
case BOL:
case EOL:
case ANY:
case GRPST:
case GRPEND:
        return(1);
case CCL:
case NCCL:
        return(pat[1] + 2);
case CLOSURE:
        return(CLOSIZE);
default:
        message(pat);
        error("in patsize: can't happen");
}
}

/* locate -- Look for c in character class at pat. */

locate(c, pat)
char c, *pat;
{
/* int i;
/*
/* /* Size of class is at pat, characters follow. */
/* for(i = *pat; i > 0; --i)
/* {    if (c == pat[i])
/*      {       return(TRUE);
/*      }
/* }
/* return(FALSE);
 C code commented out. */
#asm
; Assembly language version for speed
        POP     B       ;return address
        POP     H       ;pat
        POP     D       ;c
        PUSH    D       ;restore
        PUSH    H       ; the
        PUSH    B       ;  stack
        MOV     C,M     ;get count (*pat)
        MVI     B,0
        MOV     A,E     ;c into A
        INX     H       ;point to first character
#ifdef Z80
        DB      0EDH,0B1H       ;Z80 CPIR instruction
        JZ      locfnd  ;jump if c found
#else
loclp:  MOV     E,M     ;get char
```


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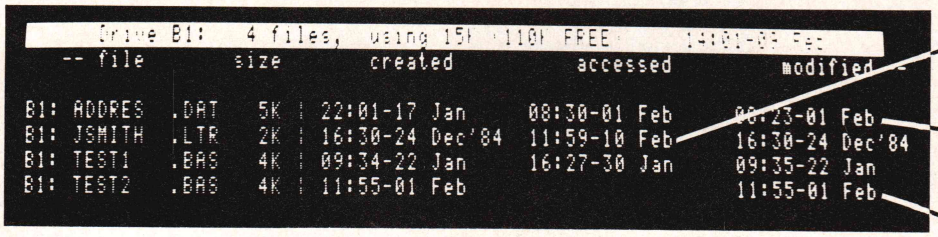

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Circle **no. 69** on reader service card.

```
        CMP     E       ;compare with c
        JZ      locfnd  ;jump if match
        INX     H       ;increment pointer
        DCX     B       ;decrement count
        MOV     D,A     ;save A
        MOV     A,B
        ORA     C       ;test for BC == 0
        MOV     A,D     ;restore A
        JNZ     loclp   ;loop if BC != 0
#endif
        LXI     H,FALSE ;return FALSE if not found
        JMP     locend  ;exit from end for profiler
locfnd: LXI     H,TRUE  ;return TRUE if found
locend: DS      0
#endasm
}

/* makepat -- Make pattern from arg, terminate at delim. */

char *
makepat(arg, delim, stpat, ppat)
char delim, *arg, *stpat, **ppat;
{
char  *lp, *starg;
char *lastp, *tmp, *esc();

starg = arg;
lastp = *ppat;
while (*arg != delim && *arg != ENDSTR)
{       lp = *ppat;
        if (*arg == ANY)
                addpat(ANY,stpat,ppat);

        else if (*arg == BOL && arg == starg)
                addpat(BOL,stpat,ppat);
        else if (*arg == EOL)
                addpat(EOL, stpat,ppat);
        else if (*arg == CCL)
        {       if (! getccl(&arg, ppat, stpat))
                        return(NULL);
        }
        else if (*arg == CLOSURE && arg > starg)
        {       if (*(lp = lastp) == BOL || *lp == EOL || *lp == CLOSURE)
                        return(NULL);   /* Closure on a null string
                                           not allowed. */
                stclose(ppat,lastp,stpat);
        }
        else if (*arg == ESCAPE && arg[1] == '(')
        {       addpat(GRPST, stpat, ppat);
                arg += 2;
                if (++lparen > 9) return(NULL);
                if ((arg = makepat(arg, delim, pat, ppat)) != NULL)
                        --arg;
                else
                        return(NULL);
        }
        else if (*arg == ESCAPE && arg[1] == ')')
        {       addpat(GRPEND, stpat, ppat);
                ++rparen;
                return(arg+2);
        }
        else if (*arg == ESCAPE && ('0' < arg[1] && arg[1] <= '9'))
        {       addpat(GRPPAT, stpat, ppat);
                addpat(arg[1], stpat, ppat);
                ++arg;
        }
        else
        {       addpat(LITCHAR, stpat, ppat);
                tmp = esc(arg);
                addpat(*arg, stpat, ppat);
                arg = tmp - 1;
        }
        lastp = lp;
        arg++;
}
if (*arg != delim)
        return(NULL);
if(! addpat(ENDSTR, stpat, ppat))
        return(NULL);
if(lparen != rparen)
        return(NULL);
return(arg);
}

addpat(c, stpat, ppat)          /* Add c at ppat, check for overflow. */
char c, **ppat, *stpat;
{
if (*ppat - stpat > MAXPAT)

        return(FALSE);
*(*ppat)++ = c;
return(TRUE);
}

/* getccl -- Expand char class at arg into pat. */

getccl(argp, patp, stpat)
char **argp, **patp, *stpat;
{
char *ccst;
(*argp)++;      /* skip [ */
if (**argp == NEGATE)
{       addpat(NCCL, stpat, patp);
        (*argp)++;
}
else
        addpat(CCL, stpat, patp);
ccst = *patp;
addpat(0,stpat, patp);  /* space for count */
dodash(CCLEND, argp, stpat, patp);
*ccst = *patp - ccst - 1;
return(**argp == CCLEND);
}

/* stclose -- Insert closure entry at *patp. */

stclose(patp, lastp, stpat)
char **patp, *lastp, *stpat;
{
char *pp, *q;

for (pp = *patp - 1; pp >= lastp; pp--)
{       q = pp + CLOSIZE;
        addpat(*pp, stpat, &q);
}
*patp += CLOSIZE;
*lastp = CLOSURE;
}

/* esc -- Map *str into escaped character, return pointer to
          next character. */
```

(Continued on next page)

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Circle **no. 48** on reader service card.

Peephole Optimizer (Listing continued, text begins on page 56)

Listing Five

```
char *
esc(str)
char *str;
{
int n, c;
char *p;
char *strcpy();

if (*str != ESCAPE)
        return(++str);
else if (*(p=(str+1)) == ENDSTR)        /* ESCAPE not special at end. */
        return(++str);
else
{       if (*p == 'N' || *p == 'n')
        {       *str = '\n';
                return(strcpy(++str,++p));
        }
        else if (*p == 'T' || *p == 't')
        {       *str = '\t';
                return(strcpy(++str,++p));
        }
        else if (*p == 'B' || *p == 'b')
        {       *str = '\b';
                return(strcpy(++str,++p));
        }
        else if ((*p | 0x20) == 'r')
        {       *str = '\r';
                return(strcpy(++str,++p));
        }
        else if (*p == '0' && (*(p+1) | 0x20) == 'x')   /* Hex */
        {       p += 2;
                *str = 0xff & xtoi(p);
                return(strcpy(++str,p += 2));
        }
        else if (*p >= '0' && *p <= '7')        /* Octal representation */
        {       for (n=0,c=0; (*p >= '0' && *p <= '7') && n<=3; ++n,++p)
                {       c = (c<<3) + (*p - '0');
                }
                *str = c;
                return(strcpy(++str,p));
        }
        else
        {       *str = *p;
                return(++p);
        }
}
}

/* dodash -- Expand set at src[i] into dest[j],
        stop at delim. */

dodash(delim, srcp, stdest, destp,)
char **srcp, **destp, *stdest, delim;
{
char *src, *cp, *tmp;
int k, junk;

src = cp = *srcp;
while (*src != delim && *src != ENDSTR)
{       if (*src == ESCAPE)
        {       tmp = esc(src);
                addpat(*src, stdest, destp);
                src = tmp-1;
        }
        else if (*src != DASH)
                addpat(*src, stdest, destp);
        else if ( src == cp || src[1] == ENDSTR)
                addpat(DASH, stdest, destp);    /* literal - */
        else if (isalnum(*(src-1)) && isalnum(src[1])
                && *(src-1) <= src[1])
                {       for(k = *(src-1) + 1; k <= src[1]; ++k)
                                addpat(k, stdest, destp);
                src++;
                }
        else
                addpat(DASH, stdest, destp);
        src++;
}
*srcp -= *srcp - src;
}

/* makesub -- Make substitution string from arg in sub. */

char *
makesub(arg, delim, sub)
char *arg, delim, *sub;
{
char *p, *q, *stsub, *tmp;

stsub = sub;
while (*arg != delim && *arg != ENDSTR && *arg != '\n')
{       if (*arg == '&')
        {       addpat(DITTO, stsub, &sub);
                addpat('0', stsub, &sub);
        }
        else if (*arg == ESCAPE && arg[1] > '0' && arg[1] <= '9')
        {       addpat(DITTO, stsub, &sub);
                addpat(arg[1], stsub, &sub);
                ++arg;
        }
        else
        {       tmp = esc(arg);
                addpat(*arg, stsub, &sub);
                arg = tmp - 1;
        }
        ++arg;
}
if (*arg != delim)
        return(NULL);   /* Missing delimiter */
if (! addpat('\0', stsub, &sub))
        return(NULL);   /* No space for sub string */
else
        return(arg);
}

/* subst -- Substitute "sub" for occurrences of pattern. */
/* Modified for optimizer. */

subst(ln, tr)
int ln;
struct trfmn *tr;
{


struct lkline *oo, *nn;
char *newline();
int line, n;

lparen = rparen = 0;
nn = tr->new;
oo = tr->old;
for (n = tr->nold; n > 0; --n)
{       if ((line = ln - n + 1) < 0)
                line += maxlines;       /* Buffer wrap around. */
        if (n <= tr->nold - tr->nnew) {
                delln(line);    /* Not enough replacements. */
                oo = oo->nextln;
        }
        else {
                if (!subline(line, oo->ln, nn->ln))
                        return(FALSE);
                else
                {       oo = oo->nextln;
                        nn = nn->nextln;
                }
        }
}
for (n = tr->nnew; n > tr->nold; --n) {         /* More lines to add. */
        newline("\n");
        if (!subline(curln, BOLSTR, nn->ln))
                return(FALSE);
        else
                nn = nn->nextln;
}
return(TRUE);
}

/* subline -- Do substitution on one line. */
subline(line, pat, sub)
int line;
char *pat, *sub;
{
char new[MAXSTR];
char *p1, *p2, *p3, *last, *pp;
int subbed;
char *amatch(), *strcpy(), *malloc();

p2 = new;
subbed = FALSE;
last = NULL;
p1 = linep[line];
while (*p1 != ENDSTR)
{       if (!subbed)
        {       pp = pat;
                p3 = amatch(linep[line], p1, &pp);
        }
        else
                p3 = NULL;
        if (p3 != NULL && last != p3)


        {       subbed = TRUE;          /* replace matched text */
                catsub( p1, p3, sub, new, &p2);
                last = p3;
        }
        if (p3 == NULL || p3 == p1)
        {       addpat(*p1, new, &p2);
                ++p1;
        }
        else    /* Skip matched text. */
                p1 = p3;
}
if (subbed)
{       if (!addpat(ENDSTR, new, &p2))
        {       return(FALSE);
```

(Continued on page 82)

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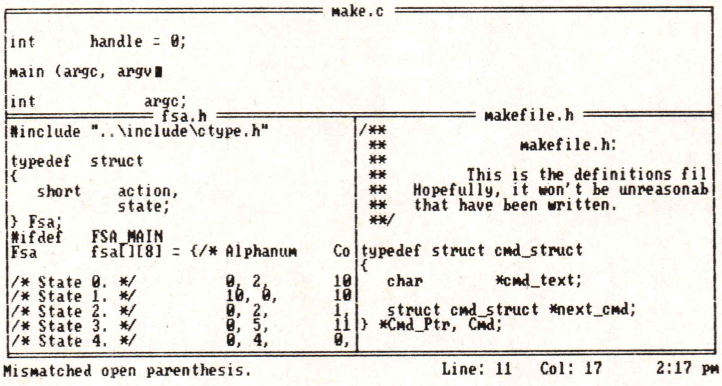

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Circle **no. 102** on reader service card.

Peephole Optimizer

(Listing continued, text begins on page 56)

Listing Five

```
        }
        else {  /* Copy new line into linep array. */
                free(linep[line]);
                if ((linep[line] = malloc(strlen(new)+1)) == NULL)
                        error("not enough memory");
                strcpy(linep[line], new);
        }
}
return(subbed);
}

/* catsub -- Add replacement text to end of new. */

catsub(p1, p2, sub, new, pp3)
char *p1, *p2, *sub, *new, **pp3;
{
char *p, *q, *esc();

for (p = sub; *p != ENDSTR; ++p)
{       if (*p == DITTO)
        {
                if (p[1] > '0' && p[1] <= '9')
                {       p1 = qstart[p[1]-'0'];
                        p2 = qend[p[1]-'0'];
                }
                for (q = p1; q < p2; ++q)
                {       addpat(*q, new, pp3);
                }
                ++p;
        }
        else
        {       addpat(*p, new, pp3);
        }
}
}

/* delln -- Delete a line. */

delln(ln)
int ln;
{
free(linep[ln]);
linep[ln] = NULL;
}
```

End Listing Five

Listing Six

```
SHLD\t\([\._a-zA-Z_][\._a-zA-Z0-9+\-]*\)
^\tLHLD\t\1
%
SHLD\t\1\t; redundant LHLD deleted
%%
\tMOV\tA,H
^\tORA\tL
\tJNZ\t\([\._a-zA-Z][\._a-zA-Z0-9]*\)
^\tLXI\tH,0
%
\tMOV\tA,H
\tORA\tL
\tJNZ\t\1\t; LXI H,0 removed following in line test
%%
\tCALL\t\([^en]*\)
\tJNZ\t\([\._a-zA-Z][\._a-zA-Z0-9]*\)
^\tLXI\tH,0
%
\tCALL\t\1
\tJNZ\t\2\t; LXI H,0 removed following library test
%%
\tCALL\t\([^en]*\)
\tJZ\t\([\._a-zA-Z][\._a-zA-Z0-9]*\)
^\tLXI\tH,0
%
\tCALL\t\1
\tJZ\t\2\t; LXI H,0 replaced following library test
\tDCX\tH
```


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```
%%
\tCALL\t\([cen]\.\)
\tJZ\t\([\._a-zA-Z]\)[\._a-zA-Z0-9]*\)
^\tLXI\tH,1$
%
\tCALL\t\1
\tJZ\t\2\t; LXI H,1 replaced following library test
%%
^\tJZ\t\([\._a-zA-Z]\)[\._a-zA-Z0-9]*\)
^\tJMP\t\([\._a-zA-Z]\)[\._a-zA-Z0-9]*\)
^\1\(:\t.*\)
%
\tJNZ\t\2\t; JZ around jump removed
\1\3
%%
^\tJNZ\t\([\._a-zA-Z]\)[\._a-zA-Z0-9]*\)
^\tJMP\t\([\._a-zA-Z]\)[\._a-zA-Z0-9]*\)
^\1\(:\t.*\)
%
\tJZ\t\2\t; JNZ around jump removed
\1\3
%%
PUSH\tH
^\tLXI\tH,\([\._a-zA-Z]\)[\._a-zA-Z0-9]*\)
^\tPOP\tD

%
XCHG\t;PUSH H POP D  around LXI H changed to XCHG
\tLXI\tH,\1
%%
PUSH\tH
^\tLHLD\t\([\._a-zA-Z]\)[\._a-zA-Z0-9]*\)
^\tPOP\tD
%
XCHG\t;PUSH H POP D  around LHLD changed to XCHG
\tLHLD\t\1
%%
STA\t\([\.a-zA-Z_]\)[\._a-zA-Z0-9+\-]*\)
^\tLDA\t\1
%
STA\t\1\t; redundant LDA deleted
%%
\tJMP\t
^\(^\t[^D][^BSW]\)
%
\tJMP\t
; unreachable code:   \1
%%
\tRET$
^\t
%
\tRET
\t; unreachable code:
%%
\tJMP\t\([\._a-zA-Z]\)[\._a-zA-Z0-9]*\)
^\1\(:\t.*\)
%
\tDS\t0\t; jump to next location removed
\1\2
%%
```

End Listing Six

Listing Seven

```
/* Library routines used by optimizer. */

atoi(str)                       /* Convert str to integer. */
     char *str;
exit()                          /* Return to CP/M */
fclose(fd)                      /* Close file with descriptor fd. */
     FILE fd;
char *fgets(str, nbytes, fd)    /* Read one line (maximum of nbytes) */
     char *str;                 /* from file into str. */
     int nbytes;
     FILE fd;
FILE fopen(name, mode)          /* Open file name with mode="r" or "w". */
     char *name, *mode;
fprintf(fd, format [, arg ] ... )  /* Formatted output routine. */
     FILE fd;
     char *format;
fputs(str, fd)                  /* Output str to file fd. */
     char *str;
     FILE fd;
free(block)                     /* Release block of memory allocated by
     char *block;               /* malloc. */
isalnum(c)                      /* Returns non-zero (true) if c is a */
     char c;                    /* letter or digit. */
char *malloc(nbytes)            /* Return pointer to block of nbytes */
     int nbytes;                /* of available memory. */
putc(c, fd)                     /* Output character c to file fd. */
     char c;
     FILE fd;
char *sbrk(nbytes)              /* Return pointer to nbytes of memory. */
     int nbytes;                /* Cannot be freed. */
char *strchr(str, c)            /* Return pointer to first occurrence of c */
     char *str, c;              /* in str. */
strcmp(str1, str2)              /* Compare strings 1 and 2. Return 0 if */
     char *str1, *str2;         /* str1==str2, negative if str1<str2, or */
                                /* positive if str1>str2. */
char *strcpy(dest, source)      /* Copy string at source to dest. */
     char *dest, *source;
strlen(str)                     /* Return length of str. */
     char *str;
strncmp(str1, str2, n)          /* Compare first n characters of str1 and */
     char *str1, *str2;         /* str2.  Return 0 if identical, negative */
     int n;                     /* if str1<str2 or positive if str1>str2. */
xtoi(str)                       /* Return integer value of hexadecimal */
     char *str;                 /* representation in str. */
```

End Listings

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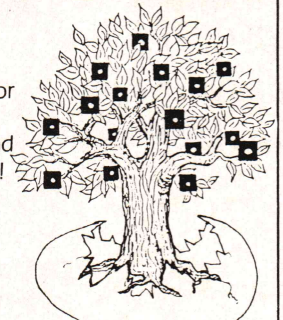

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Small-C Update

by J. E. Hendrix

What's the author of Small-C V2 been up to lately? Improvements, bug fixes, and a macro assembler.

It has been about a year since the last *Dr. Dobb's* article on the Small-C compiler, and many readers may be wondering about further developments. I have received a number of queries, mostly about structures and additional data types, but for several reasons I have not developed Small-C further.

For one thing, additions would affect nearly every part of the compiler, so it makes sense to clean up the overall structure of the compiler before proceeding. Rather than bloating the compiler with code, I would like to streamline its design, reduce its size, and improve its efficiency before adding more features. Then there is the need to free Small-C from dependence on other packages for assembling and linking its output. I consider this capability more important than additional compiler features. All of this amounts to a considerable project, and I just haven't had the time recently to spend on it.

I also wonder whether Small-C really needs to become a full C compiler to be a useful tool. It is already suitable for many applications; text processing and system utilities are obvious examples. With plenty of full-featured C compilers available at reasonable prices, I haven't felt a great urge to take Small-C beyond its present entry-level stature.

I have sent the compiler to individuals and companies involved in auto-ignition control; manufacturing of CRT terminals, electronic games, microcomputers, and circuit cards; mental health; publishing; materials management; telecommunications; engineering research; control of devices like transmitters and telescopes; and education. I have noticed an increasing interest in Small-C in education circles—high school, vocational-technical, and college. Because it is small, is written in a popular high-level language, and generates readable assembly language code, Small-C is ideal for studying what compilers do and how they work. Its one-pass algorithm and the fact that input and output default to the console make it especially convenient for studying the relationship between compiler input and output. The Small-C compiler is also a great guinea pig for term projects, giving hands-on experience in compiler construction to would-be computer scientists. And *The Small-C Handbook* makes it easy for users to quickly familiarize themselves with the language and the compiler.

I maintain a mailing list of Small-C users whom I try to keep informed of bug fixes and improvements. But because Small-C may be distributed freely (on a noncommercial basis), many people have copies that they obtained indirectly and that may be out of date. If you have version 2.1 with the new library that was introduced in May and June 1984 (*DDJ* No. 91 and No. 92), then the fixes reported below will bring you up to date.

I am still distributing Small-C for $25, *The Small-C Handbook* for $17.95, and a package of Small-C software tools for $35. Naturally, complete source code is included. To order, send a check or money order to me at the address listed at the end of the article. Include $4 for post-

---

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age and packaging plus $6 for overseas air mail. Send a self-addressed, stamped envelope for information.

People frequently ask for diskette formats other than 8-inch SSSD and North Star 5¼-inch, making it necessary for me to refer them elsewhere, and many people to whom I have sent Small-C and the tools have machines with different diskette formats, CPUs, and operating systems. In most cases, however, I do not know where they stand in porting the software or how willing they are to take referrals. So if you are running Small-C 2.1 (with the new library) on anything except an 8-inch or North Star CP/M machine and are willing to help distribute it, please let me know. Indicate (1) your machine, (2) your operating system, (3) the diskette formats you can supply, and (4) whether or not you have the Small-Tools package.

Redundant Code

David Bookbinder has observed that Small-C generates redundant code for deallocating local variables at the end of a function when the last statement is a return. The same is true if a return is the last statement in any compound statement that declares local variables. This is harmless, but it unnecessarily adds to the size of programs and it really is untidy.

Likewise, if the last statement in a function is a goto, unnecessary code for deallocating local variables and a RET is generated: because a goto would block the exit path from a function, there is no need for such code. (The compiler already eliminates the RET if the last statement is a return.) There is no problem with goto's terminating nested compound statements because goto's are not allowed if variables are declared anywhere after the opening brace of the function body—so there are no variables to deallocate.

The following patch eliminates this redundant code:

(1) Add the following line to the end of the file CC.DEF:

```
#define STLABEL 14
```

(2) Change the line in newfunc( ) (file CC12.C) that contains a call to statement( ) to read:

```
    statement( );
#ifdef STGOTO
    if(laststst != STRETURN && laststst != STGOTO)
        ffret( );
#else
    if(laststst != STRETURN) ffret( );
#endif
```


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(3) Change the line in statement( ) (file CC13.C) that contains a call to dolabel( ) to read:

```
else if(dolabel( )) laststst=STLABEL;
```

(4) Change the line in compound( ) (file CC13.C) that contains a call to modstk( ) to read:

```
#ifdef STGOTO
   if(laststst != STRETURN && laststst != STGOTO)
#else
   if(laststst != STRETURN)
#endif
      modstk(savcsp, NO); /* delete local variable
         space */
   csp=savcsp;
```

(5) Recompile, assemble, and link the compiler.

FPUTC Placement

A problem has been reported concerning the placement of the module FPUTC in the relocatable library CLIB.REL. Its placement between FPUTS and FREAD makes it precede PUTCHAR, which makes reference to it. Because L80 can't load a module that it has already passed, programs (like "words" on page 31 of *The Small-C Handbook*) that reference putchar( ) but not fputc( ) will not link properly. The correction for this condition is to move FPUTC down in CLIB.REL so that it falls between FOPEN and FREE. This is done by invoking LIB80 as follows:

```
A>LIB80
*NEWLIB=
*CLIB<. . FPUTS>
*CLIB<FREAD . . FOPEN>
*CLIB<FPUTC>
*CLIB<FREE . . >
*/E
```

You should also change the placement of FPUTC in the file NEWLIB3.SUB so it will order the modules correctly if you ever build a new library from scratch. As a precaution, you should have LIB80 list the contents of the new library (see notes below) then verify that the order exactly matches NEWLIB3.SUB. Finally, delete CLIB.REL and rename NEWLIB.REL to CLIB.REL.

fflush( ) and Auxiliary Buffers

The function fflush( ) attempts to flush an auxiliary buffer even if the file were opened for reading only. In this case, the auxiliary flush routine returns an error condition when a normal return without taking any action would

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have been appropriate. Before auxiliary buffering was added, it was not necessary to check the open mode because the "dirty buffer" status was being checked and it could not have been set for read-only files. This fix verifies the open mode before any attempt to flush a buffer. An attempt to flush a closed file now gives a normal return. Modify fflush( ) as shown below, compile, assemble, and replace in CLIB.REL:

```
FFLUSH.C
  ...
  fflush(fd) int fd; {
    if(Umode(fd) & WRTBIT) {
      if((Uauxsz && Uauxsz[fd] && Uauxfl(fd)) ||
          (!isatty(fd) && Udirty[fd] &&
           Usector(fd, WRTRND))) {
        Useterr(fd);
        return (ERR);
        }
    }
  return (NULL);
  }
```

Reset Auxiliary Buffer Pointers

When an fd that has an auxiliary buffer (because of a previous call to auxbuf( )) is closed and reopened, the next-byte and end-of-data auxiliary buffer pointers are not reset. This causes improper reading and writing. You must revise two library modules to correct this problem: CSYSLIB and AUXBUF. These modules should be revised as indicated below, compiled, assembled, and replaced in CLIB.REL:

```
CSYSLIB.C
  ...
  int
    *Uauxsz,   /* addr of Uxsize[ ] in AUXBUF */
     Uauxin,   /* addr of Uxinit( ) in AUXBUF */
     Uauxrd,   /* addr of Uxread( ) in AUXBUF */
     Uauxwt,   /* addr of Uxwrite( ) in AUXBUF */
     Uauxfl,   /* addr of Uxflush( ) in AUXBUF */
  ...
  Uopen(fn, mode, fd) char *fn, *mode; int fd; {
    char *fcb;
    if(!strchr("rwa", *mode)) return (ERR);
    Unextc[fd] = EOF;
    if(Uauxin) Uauxin(fd);
    if(strcmp(fn, "CON:")==0) {
      Udevice[fd]=CPMCON; Ustatus[fd]=
        RDBIT | WRTBIT; return (fd);
      }
  ...
```

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AUXBUF.C

```
...
extern int *Uauxsz, Uauxin, Uauxrd, Uauxwt,
    Uauxfl, Ustatus[ ];
...
auxbuf(fd, size) int fd; char *size; { /* fake
    unsigned */
    if(!Umode(fd) || !size || avail (NO) <
        size || Uxsize[fd])
      return (ERR);
    Uxaddr[fd] = malloc(size); Uxinit(fd);
    Uauxin = Uxinit;
        /* tell Uopen( ) where Uxinit( ) is */
    Uauxrd = Uxread;
        /* tell Uread( ) where Uxread( ) is */
    Uauxwt = Uxwrite;
        /* tell Uwrite( ) where Uxwrite( ) is */
    Uauxsz = Uxsize;
        /* tell both where Uxsize[ ] is */
    Uauxfl = Uxflush
        /* tell fflush( ) where Uxflush( ) is */
    Uxsize[fd] = size;
        /* tell Uread( ) that fd has aux buf */
    return (NULL);
    }
/*
** Initialize aux buffer controls
*/
Uxinit(fd) int fd; {
    Uxnext[fd] = Uxend[fd] = Uxaddr[fd];
    Uxeof[fd] = NO;
    }
...
```

Optimizing Tests Against Zero

Small-C optimizes tests against the value zero. However, in its enthusiasm, it overlooks certain unary operators that might spoil its efforts. So it optimizes if(!(i==0)) . . . ; as though it were if(i==0) . . . ;. You can fix this by making the changes indicated below to file CC32.C of the compiler:

CC32.C

```
...
hier13(lval) int lval[ ]; {
...
    else if (match("~")) {      /* ~ */
        ...
        return (lval[7]=0);
        }
    else if (match("!")) {      /* ! */
        ...
        return (lval[7]=0);
        }
    else if (match(" - ")) {    /* unary - */
        ...
        return (lval[7]=0);
        }
    ...
```

Lexcmp( )

Lexcmp( ) erroneously returns zero, indicating a match, when the first bytes that are not identical are upper and lower cases of the same letter; for instance, "Happy" and "HAY" appear to match. Revise lexcmp( ) as indicated below, recompile, assemble, and replace in CLIB.REL:

LEXCMP.C

```
...
lexcmp(s, t) char *s, *t; {
    while(lexorder(*s, *t) == 0)
        if(*s++) ++t;
        else return (0);
    return (lexorder(*s, *t));
    }
...
char Ulex[128] = {
            /**** NUL '- / ****/
              0,  1,  2,  3,  4,  5,  6,  7,  8,
              9, 10, 11, 12, 13, 14, 15, 16, 17,
             18, 19, 20, 21, 22, 23, 24, 25, 26,
             27, 28, 29, 30, 31, 32, 33, 34, 35,
             36, 37, 38, 39, 40, 41, 42, 43, 44,
             45, 46, 47,
            /**** 0-9 ****/
             65, 66, 67, 68, 69, 70, 71, 72, 73,
             74,
            /**** : ; < = > ? @ ****/
             48, 49, 50, 51, 52, 53, 54,
            /**** A-Z ****/
             75, 76, 77, 78, 79, 80, 81, 82, 83,
             84, 85, 86, 87, 88, 89, 90, 91, 92,
             93, 94, 95, 96, 97, 98, 99, 100,
            /**** [ \ ] ^ U ` ****/
             55, 56, 57, 58, 59, 60,
            /**** a-z ****/
             75, 76, 77, 78, 79, 80, 81, 82, 83,
             84, 85, 86, 87, 88, 89, 90, 91, 92,
             93, 94, 95, 96, 97, 98, 99, 100,
            /**** { | } ~ ****/
             61, 62, 63, 64,
            /**** DEL ****/
             101
            };
...
```

This patch also makes a minor change for improved efficiency and removes leading zeroes from the values in Ulex[ ] so they will not look like octal values to full C compilers.

Macro Storage

Experience has shown that the amount of storage space allocated for macro replacement strings is probably too small for the number of macros allowed. Also, the number of macros allowed may not be large enough for some programs.

The following parameters in CC.DEF have been increased to help this situation:

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```
#define     MACNBR      130
#define     MACQSIZE    (MACNBR*7)
```

You will need to recompile the compiler to effect this change. However, if you are not having problems with overflowing macro storage space, you may ignore this change.

fread( ) and fwrite( )

The functions fread( ) and fwrite( ) do not return proper values. They each take a pair of arguments indicating how many items to transfer and the size (in bytes) of an item. They are supposed to return the number of "items" actually transferred, but instead they are returning the number of "bytes" transferred.

This edit fixes these problems and makes some changes for improved efficiency in write( ). Fortunately, these changes are easily made without recompiling the compiler. Look for these functions in the files FREAD.C and FWRITE.C. Using AR.COM, extract these files from CLIB.ARC and change them as indicated below:

```
FREAD.C
  ...
fread(buf, sz, n, fd) char *buf; int sz, n, fd; {
      return (read(fd, buf, n*sz)/sz);
      }
  ...

FWRITE.C
  ...
fwrite(buf, sz, n, fd) char *buf; int sz, n, fd; {
      if(write(fd, buf, n*sz) == -1) return (0);
      return (n);
      }
  ...
write(fd, buf, n) int fd, n; char *buf; {
      char *cnt; /* fake unsigned */
      cnt = n;
      while(cnt--) {
         Uwrite(*buf++, fd);
         if(Ustatus[fd] & ERRBIT) return (-1);
         }
      return (n);
      }
```

Then compile them and put them in CLIB.REL as indicated in the notes at the end of this article. Finally, using AR.COM, put them back into CLIB.ARC.

Uputsec( )

The function Uputsec( ) in CSYSLIB always assumes that the sector being written is at the end of the file. Consequently, it always initiates the next sector with the value 1A. This is bad if you are using random access techniques, because it overwrites existing data with 1A bytes.

This fix makes Uputsec( ) realize that it is not necessarily at end of file. Using AR.COM, extract CSYSLIB.C from CLIB.ARC and change it as indicated below:

```
CSYSLIB.C
  ...
Uputsec(fd) int fd; {
   if(fflush(fd)) return (NO);
   Uadvance(fd);
   if(Ustatus[fd]&EOFBIT||Usector(fd, RDRND))
      pad(Ubufptr[fd], CPMEOF, BUFSIZE);
   return (YES);
   }
```

Then compile it and put it in CLIB.REL as explained in the notes. Finally, using AR.COM, put it back into CLIB.ARC.

hier1( )

A problem in hier1( ) (file CC31.C) causes the operators += and -= in expressions like i += p (where p is a pointer) to erroneously assign to p instead of i. If p were a local pointer, then the assignment is made to the address corresponding to the value of i, thus corrupting the system. This problem occurred because, in the effort to assign attributes to a subexpression from included primitives and subexpressions, nothing was done to isolate the attributes of the receiving field.

This is fixed by allocating a short temporary array lval3[2] for passing to store( ). Using AR.COM, extract everything from CC.ARC (or just CC3.C, CC31.C, CC32.C, and CC33.C if you already have CC?.REL files). Change hier( ) in CC31.C as indicated below:

```
CC31.C
  ...
hier1(lval) int lval[ ]; {
   int k,lval2[8], lval3[2], oper;
   ...
   if(k==0) {
      needlval( );
      return 0;
      }
   lval3[0] = lval[0];
   lval3[1] = lval[1];
   if (lval[1]) {
      if(oper) {
         push( );
         rvalue(lval);
         }
   ...
   store(lval3);
   return 0;
   }
```

Then compile the compiler (only part 3 if you already have CC?.REL files for the other parts) and link the parts with CLIB.REL, giving a new CC.COM. Finally, replace CC31.C in CC.ARC.

Leading Blanks

Frank Hayes has reported that because CP/M Plus doesn't load the command tail into its buffer (at 80H)

with a leading blank, as CP/M 2.2 does, the Small-C function Uparse( ) misses a character, often causing it to fail to recognize a redirection specification.

This correction to Uparse( ) removes the assumption of a leading blank, making Uparse( ) work correctly with either CP/M 2.2 or CP/M Plus. Using AR.COM, extract CSYSLIB.C from CLIB.ARC. Change the first few lines in Uparse( ) to read as follows:

```
CSYSLIB.C
  ...
Uparse( ){
      char *count, *ptr;
      count = 128;
      ptr = Ualloc((count = *count&255)+1, YES);
      strncpy(ptr, 129, count);
      Uvec[0]=Uarg1;
  ...
```

Compile and assemble CSYSLIB and replace it in CLIB.REL. Using AR.COM, also replace the source in CLIB.ARC. Finally, compile, assemble, and link any Small-C programs that run under CP/M Plus.

Notes

(1) In the source statements shown above, the capital letter "U" prefixes many global variable and function names. Older copies of Small-C used the underscore character "_" in this position to avoid conflicts with user-declared names. Because some versions of Macro-80 will not handle a leading underscore on external references, underscores were changed to the letter "U" to make them acceptable to Macro-80. There is no significance to the use of upper case except that it stands out in the source listing as a uniqueness prefix instead of as part of the name proper. In making corrections, you should use "U" or "_" according to the usage in your existing runtime library.

(2) The commands to replace a module in CLIB.REL are:

```
LIB80
*NEWLIB=
*CLIB<..prevmodule>
*module
*CLIB<nextmodule..>
*/E
```

"Prevmodule" is the name of the module preceding the one being replaced, "module" is the one being replaced, and "nextmodule" is the one following the one being replaced. This will leave the old library named CLIB.REL and create a new one named NEWLIB.REL. When you are sure the new library is okay, delete the original library and rename NEWLIB.REL to CLIB.REL. To find the order of the modules in the original library or to verify the new library, execute the following commands:

```
LIB80
*libname/L
*^C
```

"Libname" is the name of the library being checked.

Addendum—Small-Mac Assembler

A companion assembler to the Small-C compiler is now available. Small-Mac is a complete relocatable macro assembler package written in Small-C, for use with the Small-C compiler. It runs on 8080/Z80 machines under CP/M. Its features include low cost, ease of use, CPU adaptability, source code distribution, and educational value.

The following programs are included:

MAC	macro assembler
LNK	linkage editor
LGO	load-and-go loader
LIB	library manager
CMIT	CPU configuration utility
DREL	dump relocatable files

MAC is a two-pass, table-driven, relocatable macro assembler. It "learns" the target machine from a machine instruction table (MIT), which is created with a text editor and compiled with the CMIT configuration utility. It generates relocatable object modules in the 8-bit Microsoft format. MAC is invoked with a simple command syntax and issues descriptive error messages.

LNK combines specified object modules with modules found in specified libraries to create executable programs. Its default output is a standard .COM file. However, it can generate "load-and-go" (.LGO) files for execution at any desired address.

LGO loads and optionally executes .LGO files. It provides a convenient way to invoke operating system extensions at cold start time.

LIB builds, maintains, and lists the contents of LNK compatible libraries.

CMIT compiles machine instruction tables, lists them, and optionally configures the assembler with the resulting object table.

DREL produces a formatted dump of .REL and .LIB files.

Small-Mac instruction operands may contain expressions of any complexity. Expression operators and precedence rules follow the C language. The Small-Mac macro facility is easy to learn, remember, and use. Conditional assembly and repeat pseudo-ops are not supported at this time.

Small-Mac comes on two 8-inch SSSD diskettes containing both source and object files. A 64-page manual is included. Send $30 (plus $4 for postage and handling, plus $6 for overseas air mail) to:

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Asynchronous Protocols

by David W. Carroll

From its quiet beginnings in 1977 in Ward Christensen's MODEM program for data exchanges between dissimilar CP/M 8-bit computers, the XMODEM communications protocol has grown until it is now supported by almost every commercial communications package for 8- and 16-bit micros, by numerous public domain terminal programs, by most remote bulletin board and file exchange systems, and even by a recent implementation on CompuServe. But is XMODEM the only answer? This article focuses on the state of currently available asynchronous protocols and on the reasons for their development.

Why Protocols?

Software communications protocols are often necessary to allow communications between computer systems. Predefined protocols are required in many cases to allow reliable, error-free data communications between dissimilar computer systems. Lack of hardware DMA or interrupt capability, error checking and correction of data, binary file transmission, use of different microprocessors and disk operating systems, and provision for micro-to-mainframe links, multiple file transfers, and unattended operation are several specific reasons for using protocols.

David W. Carroll, P.O. Box 699, Pine Grove, CA 95665.
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Background

Most microcomputer systems support asynchronous serial communications. This means that each byte of data is sent as a self contained unit; the data flow is made up of discrete characters, each completely independent from the others. To allow the receiving computer to detect and interpret incoming data, a start bit is sent, followed by a given number of data bits making up the character (usually 5, 7, or 8), followed by one or two stop bits. Bell Laboratories developed this technique in 1924 for use in teletypewriter communications systems. The receiving system must resynchronize with each character sent.

In the 1950s, military and commercial teletypewriter systems implemented a simple method of error checking by adding a bit to the data to indicate the parity of the data bits making up each character. Parity checking indicates to the receiver that the number of "1" bits in the character should be either odd or even (hence "odd" and "even" parity schemes). Parity checking provides about a 94 percent probability of detecting an error in received data. There is no method for correcting a detected parity error.

A 5-bit code (like Baudot) allows for a total of 32 characters (58 characters with the figures/letters mode-shifting scheme used in telex systems) and is still used in telex communications today. Many other character-coding schemes have been developed, but the 7-bit United

A status report on what Bell Labs, with some help from Ward Christensen and others, hath wrought.

States American Standard Code for Information Interchange (USASCII or simply ASCII), defined in the ANSI X3.1 standard of 1967, is the most widely used standard for micros. This code has 128 possible characters and includes numbers, upper- and lower-case English alphabet, punctuation, and control codes.

The 7-bit ASCII code, with or without parity checking, has long been a standard for time-shared mainframe remote terminal communications, mainly because the Teletype ® model 33 machine was the most common time-sharing terminal during the 1960s and 1970s.

Simple Protocols

The advent of microcomputers and low-cost modems in the past 10 years has generated a need for a simple, inexpensive and reliable way to exchange program and data files containing 8-bit binary data, as well as text files made up of standard ASCII characters. The IBM PC further expanded this need with its extended 8-bit character set made up of 256 characters. As more and larger data files are being transmitted over ordinary telephone lines, more elaborate error detection and automatic correction are also required.

In asynchronous time-sharing remote links, data is sent arbitrarily by the transmitting system, without regard for the capability of the receiving system to accept it. When the character is sent on to a terminal simply for display or for storage in a memory buffer, this does not present a problem. However, when files of data are transferred, the receiving system periodically must dump the data to a disk file. In many hardware configurations, this requires all of the system's resources; it can no longer handle incoming data during the dump period. Thus, to avoid data loss the receiver must have some way to halt the data flow from the sender.

Some simple protocols have been developed to allow unformatted text transmission between mainframes and microcomputers. Three basic methods control the data flow: handshaking, delay, and interruption. Use of handshaking involves sending a character (usually a carriage return) at the end of each line and requires the return of a character (usually a line feed) before flow resumes. The second alternative is for the sending system to delay a predetermined number of seconds after transmitting each line of text to allow the receiving system to empty its data buffer when required; this method works, but it can slow down communications dramatically. The interruption method has the system send data until it receives an interrupt character then pause until it receives the resume character. This protocol is perhaps the most efficient because it allows continuous transmission until the buffer is full, ensuring maximum throughput.

CR-LF Protocol

One common file transfer method used to prevent buffer overflow in time-sharing systems is to transmit one ASCII line of text at a time, including the carriage return character, then to wait for the receiver to send a line feed as acknowledgement. Often a delay of several seconds is added before the next line is transmitted. CR-LF is the most common example of the handshaking technique, although prompt sensing is another popular method used for uploading to an editor or BASIC interpreter.

XON—XOFF File Capture Protocol

Possibly the most common text file transfer protocol in use today is the file capture or XON–XOFF–protocol offered on almost all time-shared mainframe computers. This protocol detects two characters—usually ASCII DC1 and DC3 (^Q and ^S). XOFF or ^S pauses transmission and XON or ^Q resumes transmission. This protocol, another holdover from teletypewriter terminals, was used on teleprinters for paper tape operations.

Today, this file capture mode is used to transfer text files between dissimilar computer systems. Data is

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captured to a memory buffer, and XOFF is sent when the buffer is nearly full. When transmission stops, the data in the buffer is written to disk. Care must be taken to ensure that the text file does not contain any ^Q or ^S characters (as in WordStar files).

This protocol is supported by CompuServe, The Source, all three major data networks, and most time-sharing host computers and bulletin board systems. It supports only parity checking and 7-bit ASCII file transfers on most systems.

HEX File Conversions

Many older host computers and front-end communications processors do not support 8-bit data transfers over asynchronous links. How then can these systems (like CompuServe until recently) send binary data files?

A program converts the binary data to ASCII characters representing the hexidecimal value of the data. Thus, each 8-bit data byte ends up as two ASCII characters. For example:

Binary		ASCII
0110 1011	→	6B
1110 0001	→	E1
0011 1111	→	3F

These "characters" can be sent easily as text—but what about errors? To resolve this problem, a line format is used that includes a checksum of the characters, similar to Intel Hex format (CP/M-80, etc.). Obviously, this method is both inefficient and time consuming: it involves translations at both ends and more than doubles the transmitted size of the original file.

CompuServe supports this protocol, but it is becoming less popular than some others, like XMODEM.

XMODEM

Determined to solve the problem of file transfer, Ward Christensen, a skilled programmer in Chicago, designed a block-oriented file transfer technique that allows for text *and* binary file transfer with simple, yet effective, error checking. His first version of the program, called MODEM, was written in September 1977 and appeared on CP/M User Group Disk 25. It allowed two microcomputer users, each running the CP/M 80 operating system, to exchange both ASCII text files and 8-bit binary .COM files by modem or direct connect. (In the early days, there were many different types of CP/M systems, and most disk formats were not compatible, so directly transferring files over a communications link was often the only way to move programs from one type of computer to another.)

MODEM protocol transfers are made up of blocks of 132 bytes: four header bytes, consisting of a start of header (SOH) ASCII character, the 8-bit block number, the one's complement of the block number, and the 8-bit checksum, plus 128 data bytes. The receiver controls the sending of each block and any necessary retransmissions by sending an acknowledge (ACK), negative acknowledge (NAK), or cancel (CAN) ASCII code in response to each block. Timeouts are used as a further check of transmission accuracy and for resynchronization.

By 1979, BYE, an unattended system control program, and XMODEM, the unattended version of MODEM, were operating in bulletin boards across the country. Most file transfer systems were based on MODEM, BYE, and XMODEM, as well as on the programs written (in part by Ward Christensen) for one of the first microcomputer-based Computer Bulletin Board System (CBBS) ® in Chicago.

A large number of "improvements" to the first MODEM program have been written, and dozens of commercial and public domain programs now support the XMODEM protocol. Recently, the basic protocol definition was expanded to include optional Cyclic Redundancy Check (CRC) error checking, an improvement on the simple checksum method used in the original programs. CRC ensures a 99.99 percent probability of detecting errors. The CRC polynomial is specified by the CCITT international telecommunications standards organization.

MODEM7 Protocol

Mark M. Zeigler and James K. Mills wrote the MODEM7 CP/M 80 program in 1980. The MODEM7 protocol is an adaptation of the original MODEM/XMODEM protocol defined by Ward Christensen. The MODEM7 program adds the ability for wildcard and multiple file transfers to the basic XMODEM protocol, as well as optional CRC error checking.

Bruce R. Kendall translated the MODEM7 program to 8086 code for CP/M 86 and MSDOS in 1983; it is still used by many as a primary communications program. The MODEM7 protocol is supported by the FIDO bulletin board software.

Interestingly, Crosstalk and Crosstalk XVI (probably the most popular commercial communications program) do not properly support XMODEM transfers to all systems and do not support CRC mode at all. A public domain subprogram is available for 16-bit systems to correct this problem.

KERMIT Protocol

KERMIT (the protocol, not the frog) was developed at Columbia University and released to the public domain to allow efficient transmission of 8-bit binary data on systems that are hardware limited to 7-bit ASCII. The KERMIT method encodes the binary data into acceptable ASCII characters for transmission, but it uses more than four bits of each character (see the HEX scheme above) and uses a block rather than a line error-checking protocol to achieve much greater efficiency. KERMIT also allows multiple file transfers and master/slave operations.

KERMIT is available for most microcomputers and many mainframes at little or no cost. It presently is supported by the FIDO bulletin board system and Telois commercial micro communications software. It may become a widely used standard in the near future.

Microcom Networking Protocol

The Microcom Networking Protocol (MNP) is an interesting attempt by a commercial company to define an industry standard. Microcom, maker of modems and communications software, defined their protocol in 1982. It has been accepted by IBM, Tymnet, Telenet, and some others as a standard. Also, the data networks accept it as a way to provide an error-

free "local" link to their access nodes.

MNP is used in Microcom's ERA 2 communications software and in IBM's Personal Communications Manager program (written by Microcom). It is also supported by the latest version of RBBS-PC (12-4A1).

CompuServe A & B Protocols

CompuServe has defined two protocols for use with its VIDTEX service and provides software to support them on several computers, including most TANDY (TRS-80) computers, the Apple, and the IBM-PC.

CompuServe A protocol, originally developed to allow binary file transfers from the mainframes used by the service, was later updated to the current protocol. It is used to upload and download binary files. CompuServe B protocol is used primarily with Tandy (Radio Shack) TRS-80 computers for file transfers and support of full-color video graphics (VIDTEX) capabilities.

CompuServe also supports BIN and HEX file 7-bit ASCII transfers in modified Intel Hex format.

ANSI X3.28 Protocol

With the demand for reliable communications, it is surprising that the ANSI X3.28 protocol (originally defined in 1971) was not implemented on microcomputers until this past year. The X3.28 protocol is similar to MODEM7 and KERMIT. It provides block transmission with CRC-type error checking, remote system master/slave control, and multiple file transfers.

Artisoft Inc. of Tucson, Arizona, has included X3.28 protocol support in its Envoy-PC communications software, as well as file capture and XMODEM. Recently, X3.28 has received attention as a possible protocol for use in local area networks.

Specialized Protocol Software

Several software vendors have developed their own protocols for use between systems running their programs. Some of these include the following.

Crosstalk

Crosstalk and Crosstalk XVI by Microstuf both support a 256-byte block, error-checking protocol (also called CLINK) similar to MODEM7 that allows multiple file transfers. Later versions of Crosstalk also support XMODEM.

Smartcom

Smartcom and Smartcom II support the Hayes Verification Protocol, a special error-checking protocol designed by Hayes Microcomputer products for file transmission. Smartcom II also supports the XMODEM protocol.

Telink

The Telink protocol is supported by the Telink program and Minitel public domain communications program, written by Tom Jennings, and by the FIDO bulletin board system, also authored by Jennings. All programs support MODEM7 and XMODEM as well.

Move-It

Move-It from Woolf Software uses a proprietary "packet" protocol with 16-bit checksums, message numbering, and remote multiple file transfer capability. Move-It does not support XMODEM.

MITE

MITE (Mycroft Intelligent Terminal Emulator) from Mycroft Labs supports all of the above protocols (except Telink) plus the following:

- XMODEM checksum and CRC
- MODEM7 checksum and CRC (called XMODEM/Batch)
- MITE batch block protocol (see *DDJ*, August 1982)
- IBM PC (text protocol from IBM Asynchronous Support Program)
- TEXT (simple Hex transfer protocol)

ASCOM

The ASCOM program from Dynamic Microprocessor Associates supports XMODEM (called CPMUG) as well as two checksum block protocols, BLOCK and BLOCKV.

Summary

A number of asynchronous protocols have evolved to fill the need for reliable file transfers of both text and binary data between various types of mainframes and microcomputers. The most widely used standard is the XMODEM protocol originally defined by Ward Christensen, but even this protocol has four possible formats (checksum/CRC and single file/batch). Most commercial and public domain file transfer programs support at least the basic checksum, single file version of the XMODEM protocol. XMODEM is simple, fairly unambiguous, and easily implemented in a variety of languages, from C to BASIC.

Transfers from 7-bit mainframe host systems are still a clumsy and time-consuming process. The KERMIT protocol, which improves the efficiency of these transfers, is now available in a number of formats for many different computers.

Several other proprietary protocols have been developed, but none has received the widespread acceptance of XMODEM. With XMODEM so well entrenched, it is unlikely to be replaced by another protocol for several years, if at all.

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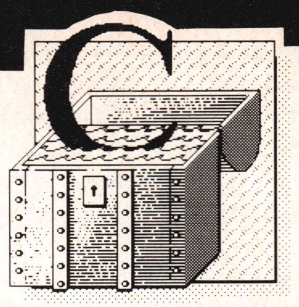

by Allen Holub

The main topic of this month's column is the Unix[1] "make" utility. We'll talk about how make works, review a few versions that run under MSDOS, and present the complete source for a rather stupid, but nonetheless functional, version of make for MSDOS.

However, before leaping into make, I'd first like to thank everyone who sent in sort routines. Several of the routines are quite spiffy; we'll definitely have another sorting column in the next few months.

Next, some good news for Lattice C users: they've finally cleaned up their manual. The old manual was so poorly organized as to make the compiler almost useless to someone who wasn't thoroughly familiar with Unix. Critical information was scattered over several appendixes and a myriad of technical bulletins. This wouldn't have been a problem if Lattice had published a new index with each addendum to the manual, but no such luck. As far as I can tell, the new manual uses the same text as the old one; however, it's now organized into a coherent whole with a real index (they even highlight function names in blue). If you own version 2.1x or later of the compiler, you can get a free update to the new version (2.15) and a copy of the new manual by sending Lattice your original release disks. Older versions of the compiler (including Microsoft and Lifeboat versions) can be updated for a fee ranging from $50 to $100, depending on the version. If you have an older version of the compiler and just want the new manual, send Lattice the table of contents and index from the old manual and they'll send you the new one (but no software update).

Finally, while rooting through a friend's back issues of the *PC Tech Journal*, I discovered MSDOS's undocumented SWITCHAR feature in an article by J. Eric Roskos (August 1984, page 73). It's a constant annoyance to me that command.com insists on using \ to separate directory names in a path and / as a command line switch designator (Unix programmers are used to / and -, respectively). This seemed all the more onerous when I discovered that MSDOS itself accepts either a \ or / in a path name. Only command.com and a few utility routines insist on specializing the two.

Well, it turns out that if you include the line

```
SWITCHAR = -
```

in your config.sys file, command.com will use a - instead of a / as its command line switch designator (you can replace the - with any printing character). Because / is no longer special, command.com passes it through to DOS where it's accepted as a legal path name designator. Moreover, the path printed by the "prompt $p" command will now use slashes instead of back-slashes when it displays the path!

I've no idea how this mechanism actually works, though I suspect it operates in ways similar to an environment variable. If anyone can enlighten me, please write. On page 113 of the same issue of the *PC Tech Journal*, Daniel Frank shows how to use DOS function 37 (also undocumented) to get the current switch character. Frank also presents a few SWITCHAR caveats. To summarize: RESTORE can get very confused if the SWITCHAR is set when you run BACKUP, so don't use the SWITCHAR if you're doing a backup. The same article gives a patch to RESTORE to fix this problem; the interested reader can find it there.

Unfortunately, in a fit of perversity, Microsoft elected not to support SWITCHAR in DOS version 3. The operating system spits out the message: "Unrecognized command in CONFIG.SYS." Argh. All is not lost, though. Unipress, the manufacturer of Ps-make, reviewed below, sells a program that changes the switch character, and this program *does* work with version 3.

Make

Make is one of those deceptive utilities: you can't figure out why anyone would bother to use it until you actually do use it, then you can't figure out how you got along without it. Make takes as input a makefile, which describes all the modules in a large program and the relationships between the modules. Using the makefile, make determines which modules must be recompiled at any given moment and then compiles them (and only them). It's like an intelligent batch utility that knows how C programs and C compilers work and does only those actions that are absolutely necessary.

The best way to explain make is with an example. You've an executable program called farm.exe. The original source is split up into three modules: cow.c, pig.c, and farm.c. All three modules have an #include <stdio.h> statement in them. In addition, cow.c and pig.c have an #include <animals.h> statement. Now, if you change something in cow.c, you need to recompile cow.c and then relink the new cow.obj into farm.exe. If you change something in animals.h, you need to recompile both cow.c and pig.c then relink. If you change stdio.h, you need to recompile everything. Make describes the relationships between these various files as "dependencies." The

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makefile is a list of these dependencies. A makefile for the program just described is shown in Figure 1 (below).

The # designates a comment line. Farm.exe "depends on" cow.obj, pig .obj, and farm.obj. This means that if any of the files cow.obj, pig.obj, or farm.obj have been changed more recently than farm.exe, then farm.exe must be remade—by executing the line: link \lc\s\c cow pig farm,farm, con,\lc\s\lc. Similarly, if any of the files pig.c, stdio.h, or animals.h have been changed more recently than pig.obj, then pig.obj must be remade (using the command lc -ms -i\lc\ -i\lc\s\ pig). The actions associated with each set of dependencies can extend to several lines. To activate the process, you just type the command make. Make reads in the makefile and, using the information found there, figures out what to do and does it.

Make supports several options that make your life a little easier. You may use macros to save some typing. A macro is created by placing the following definition at the head of the makefile:

name = stuff

```
#
#  Make farm using the Lattice C compiler.
#

farm.exe:       cow.obj pig.obj farm.obj
                link \lc\s\c cow pig farm,farm,con,\lc\s\lc

cow.obj:        cow.c stdio.h animals.h
                lc -ms -i\lc\ -i\lc\s\ cow

pig.obj:        pig.c stdio.h animals.h
                lc -ms -i\lc\ -i\lc\s\ pig

farm.obj:       farm.c stdio.h
                lc -ms -i\lc\ -i\lc\s\ farm
```

Figure 1.
A Simple Makefile

```
#
#  Make farm using the Lattice C compiler.
#

INCLUDES = stdio.h animals.h
OBJECTS = cow.obj pig.obj farm.obj
COMPILE = lc -ms -i\lc\ -i\lc\s\

farm.exe:       $(OBJECTS)
                link \lc\s\c $(OBJECTS),farm,con,\lc\s\lc

cow.obj:        $(INCLUDES) cow.c
                $(COMPILE) cow

pig.obj:        $(INCLUDES) pig.c
                $(COMPILE) pig

farm.obj:       stdio.h farm.c
                $(COMPILE) farm
```

Figure 2.
A Makefile with Macros

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where name is the macro name and stuff is the text to be substituted. In the makefile the macro is expanded by $(name). Our original makefile, rewritten using macros, is shown in Figure 2 (page 97).

You can simplify the makefile even further. Notice that all .c files are converted to .obj files with the same set of actions. Make provides a mech-

```
#
#  Make farm using the Lattice C compiler.
#

INCLUDES = stdio.h animals.h
OBJECTS = cow.obj pig.obj farm.obj

.c.obj:
                lc -ms -i\lc\ -i\lc\s\ $*

farm.exe:       $(OBJECTS)
                link \lc\s\c $(OBJECTS),farm,con,\lc\s\lc $*

cow.obj:        $(INCLUDES)
pig.obj:        $(INCLUDES)
farm.obj:       stdio.h
```

Figure 3.
A Generic Makefile

```
#
#  Make farm using the Lattice C compiler.
#

farm.exe:       cow.obj pig.obj farm.obj
                link \lc\s\c cow pig farm,farm,con,\lc\s\lc

cow.obj:        cow.c stdio.h animals.h
                lc -ms -i\lc\ -i\lc\s\ cow

pig.obj:        pig.c stdio.h animals.h
                lc -ms -i\lc\ -i\lc\s\ pig

farm.obj:       farm.c stdio.h
                lc -ms -i\lc\ -i\lc\s\ farm

#
#  Null targets not needed in a real makefile:
#

animals.h:

stdio.h:

pig.c:

cow.c:

farm.c:
```

Figure 4.
An Mkfile

anism for doing this sort of repetitive action, called a "generic dependency". Consider the makefile shown in Figure 3 (page 98).

The lines:

```
.c.obj:
        lc -ms -i\lc\ -i\lc\s\ $*
```

say "to turn a .c file into an .obj file, execute the line lc -ms -i\lc\ -i\lc\s\ $*" where $* is a predefined macro that evaluates to the root portion of the file being made (the one to the left of the : on the dependency line). For example, given the dependency line:

```
foo.obj: foo.c rat.h
```

$* will evaluate to the string foo. In the case of this generic dependency, make assumes that all .obj files depend on a .c file having the same root name. So, when foo.obj is being made, a dependency on foo.c is assumed, and it need not be listed on the dependency line.

There are several commercially available make utilities that run on MSDOS. (See the review of MSDOS C compilers on page 30 for compilers that include a make utility in the standard distribution package. You can't have a make for CP/M because you can't time and date stamp a file.) I looked at three of these: Polymake (by Polytron), Ps-make (by Unipress Software), and Pmaker (by Phoenix).[2] Of these, Polymake (at $99) is both the least expensive and the most complete implementation of make. Ps-make (at $179) is missing some of the features of Polymake. Pmaker, the Phoenix product (at $195), is both the most expensive and the most limited of the three versions. The Pmaker manual is extremely sparse. Pmaker supports virtually no command line options and only a stripped-down set of internal utilities (no predefined macros, no generic dependencies). It does come with a utility that creates makefiles (by going into your source code and looking for #include statements), but because my makefiles are often a little weird, I found this utility pretty useless. Frankly, I don't think that Pmaker is worth the money. In fact, the version of make presented at the end of this column is almost as powerful as the Phoenix product—and it's free. I'll therefore limit my remarks to Polymake and Ps-make.

Polymake

Polymake supports all the make features described above. It has 13 command line options:

-a
Rebuild all targets, even if time and date say that you don't have to.

-b <file>
Look for a file called builtins.mak—Polymake supports a default actions file in which you define things like .c.obj. or macros that are used a lot.

-c
Create a batch file rather than doing the action—this lets you use Polymake with DOS version 1.

-d
Echo an execution trace as actions are performed—debug mode.

-f <file>
Use <file> as the makefile instead

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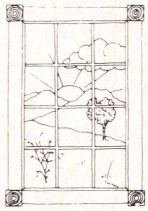

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of "makefile."

-i

Ignore errors returned from the programs.

-k

Keep working and ignore error codes returned from a process. (Like the Unix version, if any program invoked by Polymake returns a value other than 0, Polymake terminates. This can be annoying if you want to compile 85 modules and go to lunch, redirecting all the error messages into an error log file. The -i option suppresses this automatic termination. From reading the manual, I'm not clear about the differences between -i and -k. I've been using -k.)

-n

Print out the various actions but don't actually execute them—this is useful for debugging a makefile.

-p

Print out a representation of the makefile after it's been interpreted.

-q

Don't print out error messages from commands.

-r

Don't use any builtins.mak files (see option -b above).

-s

Don't echo commands (silent).

-t

Touch. (Perhaps the most useful option supported by make, -t is for the situation where you change a comment in stdio.h and now make thinks that all 97 modules of your program monster.exe have to be recompiled; make -t modifies all the times and dates for files to be made so that they look as if they've been recompiled, but it doesn't actually recompile them. Polymake also comes with a touch utility (invoked from MSDOS with "touch <file list>") that sets the time and date of the indicated files to the current time and date.)

There's also a rich set of predefined macros:

$(name)	Expand macro "name"
$$	$ sign
$@	Name of current target
$*	Root of current target
$<	Source being used to make current target
$?	All sources that have been modified more recently than current target
$( )	Null string
$(mflags)	Command line flags (so that make can invoke itself recursively)
$(cwd)	Current working directory

Finally, Polymake supports several internal options, as well as generic dependencies. Although I won't describe all of them here, one is quite useful: the local input script. This feature is for programs, such as librarians and linkers, that sometimes need to use input files rather than the command line. For example, you can have so many files to link together that they won't all fit on a DOS command line. In this case, you put the command line into a file then call link with @file given on the command line. Local input scripts let Polymake create these input files for you. The example given in the manual illustrates the process pretty well:

```
text.exe : t1.obj t2.obj t3.obj
```


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```
  link <@<
t1+
t2+
t3
test.exe
test.map
\lc\s\lc.lib
<
```

All text between the second and third < sign is put into a file called lis_qqq.tmp. Link is invoked with the line link @lis_qqq.tmp. The @ in this example can be replaced by any printing character. For example,

```
text.exe: t1.obj t2.obj t3.obj
  link <<<
text
<
```

will execute link <lis_qqq.tmp; lis_qqq.tmp will contain the single line "text." The temporary file is deleted when Polymake is done with it.

As you can probably tell, I like Polymake. I've been using it for a month now and haven't found any problems yet. My only complaint is that the manual doesn't have an index (which will make it hard to find anything if you're not familiar with the Unix make). On the other hand, Polymake sticks pretty close to the Unix model, so you may not need to consult the manual very often.

Ps-make

As I said earlier, Ps-make is more limited that Polymake, but it does do everything I consider to be essential: generic dependencies, $@, $*, $<, and macros. Several command line options are supported (there is some overlap with Polymake):

-f<file>
Use <file> as the makefile.
-o<file>
Use <file> as name of batch file (see -b).
-b
Create a batch file instead of executing commands.
-B
Beep before exiting.
-c
Don't convert to lower case when evaluating rules.
-d
Print file modifications times used in comparisons.
-e
Ignore various environment variables—the name of the default rules file (builtins.mak in Polymake) is kept in an environment variable.
-p
Print the generated dependency tree.
-s
Don't execute commands as they're executed.
-t
Touch.
-v
Force Ps-make to verify that a generated file exists before using it.

A MAKE Utility in C

One of the first utilities I wrote for MSDOS was the version of make given here. The program's called mk (i.e., a make with half of it missing). Mk is pretty stupid; it doesn't support macros or command line switches. On the other hand, it does do the critical job: recompile only those parts of a large modular program that need it. I was glad to have it before I got my copy of Polymake, and it is, after all, free. Mk was designed to help maintain large C programs, and it works quite well in this application, but it won't do everything that the real make can do.

Mk uses a makefile called "mkfile," which, like the real makefile, lists all the dependencies needed to make a program. If mk is invoked with a name as an argument (i.e., mk foo.exe), it will make the indicated file; that is, it looks in the mkfile for the indicated filename to the left of a colon on a dependency line and starts the make from that point. If no file is specified on the command line, the first file listed in the mkfile is made.

The mkfile itself has a more restricted syntax than a real makefile:

(1) A # sign in column 1 designates a comment line. The # must be in the leftmost column.

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(2) The dependency line comes first. It uses the format "target: dependencies". The colon is required (an error message is printed if it's not there). The dependencies are delimited from one another with white space (any combination of tabs and blanks). The dependencies must all be listed on a single line; however, any line terminated with a back-slash (\) will be continued to the next line. For example:

```
This is\
one line\
of text.
```

(3) All files listed as dependencies must be used as targets somewhere in the mkfile (i.e., to the left of a colon). A null target (one consisting of a single filename followed by a colon but no dependencies, this in turn followed by a blank line) is permitted.
(4) All lines following the dependency line, up to a blank line, are the actions executed to make the target. The blank line is required to terminate the block of actions. Any number of blank lines are permitted as a terminator, but any nonblank line following a blank line is assumed to be a new dependency line.
(5) Targets having no dependencies will always be made. For example,

```
listing:
    print foo.c bar.c rat.c
```

will always execute the print command.
(6) For the sake of comparison, all nonexistent files are considered to exist and to be very old, so a nonexistent file listed to the left of a colon will always be made. The dates and times associated with a target are updated as soon as the target is made.

Figure 4 (page 98) is a mkfile version of the makefile in Figure 1. Here the blank lines are required, as are the various null targets at the end of the file (for animals.h, stdio.h, etc.).

The listing for mk starts on page 104; mydos.h (#included on line 3) was presented last month. There are several macros at the head of the listing. #including the #define on line 6 will cause mk to generate a trace as it parses the mkfile, but it won't actually try to do anything. MAXLINE (on line 8) limits the number of characters in a line (lines continued with a terminating \ are considered to be one line). MAXBLOCK and MAXDEP (lines 9 and 10) are the maximum number of actions that can follow a dependency line and the maximum number of dependencies, respectively. MAKEFILE (line 12) is the name used for the makefile. The three macros on lines 24–26 have horrible side effects, so be careful with them (don't ever say skipwhite(++s)).

I suspect that the real make sets up a dependency tree, a multi-way tree that has the major file to be made as its root and dependencies as children. Mk doesn't work that way. Mk reads in the entire mkfile before it tries to do anything. If it gets lost (or finds a syntax error), an error message is printed and mk terminates.

The makefile is organized as a binary tree, ordered alphabetically by target filename; the tree nodes are typedefed on lines 38–47. Lnode and rnode are pointers to children in the tree. The target filename (the one to the left of the equals sign) is used as the search key and stored in the being_made field.

The dependencies and the actions following the dependencies are put into two argv-like arrays of pointers to strings. The fields depends_on and do_this are used like argv to access these arrays. Both arrays are terminated with a null entry, so the equivalent of argc isn't required.

Finally, the time field holds the file create time and date returned by DOS. The time and date are concatenated (with the date in the most significant word). This enables the time field to be used as a single number in comparisons.

Most of the routines are commented well enough to be self-documenting, but there are some exceptions. Gtime( ) (lines 97–137) gets the time and date for a file from DOS, concatenates the time and date together, and returns the concatenated result. The functions gregs( ) and dos( ), used to access DOS, were presented in

this column last month.

The assignment on lines 129–30 merits some attention. Regs.x.dx and regs.x.bx are both shorts. A short, shifted left 16 bits, evaluates to 0, so dx has to be cast into a long before the shift. Similarly, if regs.x.cx isn't cast into a long, the | will behave unpredictably, depending on whether sign extension is active. However, now we have to AND the result of the type conversion with 0xffff to defeat the sign extension (or else we may end up setting the entire top 16 bits to 1).

The function getline( ) (lines 200–251) is useful enough to merit some notice, too. It works something like gets( ) except that it recognizes line continuation (lines ending in \) and it allocates buffer space using malloc( ). I've used it in several other programs.

The final routine to look at here is make( ) (lines 302–381); all the real work performed by mk is done here. Make( ) is recursive. To make a single object, you have to make the dependent files. If any of the dependent files were remade, you then have to perform the action on the current file. When make( ) returns, the dates on the remade files will have been modified to the current date. Consequently, the time and date comparisons for the target and the dependent file (on line 339) must follow the recursive make( ) call (on line 327). If any of the dependencies were younger than the target, doaction is incremented (line 350). We don't actually do the action on line 350 because we don't want to do it several times.

Finally, mk uses a system( ) call (line 368) to execute each action line. In Unix, system( ) creates a parallel process running the shell then passes its argument through to the spawned shell. Because Unix supports true multitasking, the only real penalty involved in a Unix system( ) call is the time it takes to activate the shell.

MSDOS is another matter. System( ) actually reads a *second copy* of command.com into memory then executes the command line with this second copy. Because command.com uses about 21K and because the program being invoked takes up some space, as does mk itself (about 15K in my version), memory can disappear pretty fast. I've a bunch of memory, so this limitation hasn't been a problem, but it may be for you.

There are two solutions. The better of these works only if you aren't going to use any functions internal to command.com (more importantly, you can't run a batch file from inside mk). The Lattice compiler supplies several system( )-like procedures. In particular, the various fork( ) functions (forkv, forkl, forkvp, forklp) will execute another program directly, without the additional invocation of command.com. These functions are something of a misnomer as they don't behave like the Unix fork( ) function; however, at the cost of a little overhead (you have to extract the program name from the action), you can use a fork( ) function instead of a system( ) call to do the action. If your compiler doesn't have a fork( ) or a system( ) call, you can create one using the DOS version 2 EXEC function (0x4b). I can print a system( ) function in this column at a later date if enough people need one, but most compilers seem to come with this function.

The second solution to the space problem is more involved. Instead of doing the action from inside mk, the program can create a .bat file and exit—you can then execute the batch file from outside mk. If you're running DOS version 1, you have to use this procedure because the EXEC function isn't supported. The problem here is that the time and date associated with a target are dynamically updated by mk when the target is remade (on line 374 of the listing). This new time is used by previous invocations of the subroutine make( ) to see if they need to do an action. Because gtime( ), the routine that does the updating, looks at the real file, it can't be used for updating if this file hasn't actually been modified. So, in addition to replacing the system( ) call on line 368 with a fprintf( ) call, you need to replace the gtime( ) call on line 374 with either a representation of the current time and date or with some constant that looks like a very young time and date (i.e., 0x7fffffffL).

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One final caveat: system( ) prepends the argument /c to the command when it executes EXEC. (The process is described in section 7 of the version 3 *DOS Technical Reference* and in the version 2 manual somewhere.) Anyway, if you've used the SWITCHAR feature described earlier, DOS will be confused by the /, so set the switch character back to / before you use mk.

Erratum: I'm embarrassed to admit that my complaints last month about the erase-screen and erase-inline functions of ANSI.SYS were unfounded. I was using puts( ) to do my output and the extra newline character came from puts( ), not from ANSI.SYS.

Notes

[1]Unix is a registered trademark of Bell Labs.

[2]Polymake, Ps-make, and Pmaker are registered trademarks of Polytron, Phoenix, and Unipress Software, Inc., respectively.

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C Chest Listing (Text begins on page 96)

```
 1: #include <stdio.h>
 2:
 3: #include <mydos.h>

 4: /*-------------------------------------------------------------------------*/

 5: #ifdef  NEVER
 6: #define DEBUG 1             /* Include for debug diags in make()     */
 7: #endif

 8: #define MAXLINE  (80*10)    /* Maximum input line length             */
 9: #define MAXBLOCK 64         /* Max number of lines in an action      */
10: #define MAXDEP   32         /* Max number of dependancies            */
11: #define COMMENT  '#'        /* Delimits a comment                    */
12: #define MAKEFILE "mkfile"   /* Name of makefile                      */
13: #define OPEN     0x3d       /* Dos function call to open a file      */
14: #define CLOSE    0x3e       /* Dos function call to close a file     */
15: #define DATETIME 0x57       /* " to get or set file's date & time    */

16: #define DEFTIME  0x0        /* The default time returned by gtime when a file
17:                             * doesn't exist.
18:                             */

19: /*-------------------------------------------------------------------------
20:  *      iswhite(c)      evaluates true if c is white space.
21:  *      skipwhite(s)    skips the character pointer s past any white space
22:  *      skipnonwhite(s) skips s past any non-white characters.
23:  */

24: #define iswhite(c)      ((c) == ' ' || (c) == '\t')
25: #define skipwhite(s)    while( iswhite(*s) )        ++s;
26: #define skipnonwhite(s) while( *s && !iswhite(*s) ) ++s;

27: /*-------------------------------------------------------------------------
28:  * The entire makefile is read into memory before it's processed. It's
29:  * stored in a binary tree composed of the following structures:
30:  * depends_on and do_this are argv-like arrays of pointers to character
31:  * pointers. The arrays are null terminated so no count is required.
32:  * The time field is a 32 bit long consisting of the date and time
33:  * fields retuned from a DOS 0x57 call. The date and time are
34:  * concatanated with the date in the most significant 16 bits and the
35:  * time in the least significant. This way they can be compared as
36:  * a single number.
37:  */

38: typedef struct _tn
39: {
40:         struct _tn      *lnode;     /* pointer to left sub-tree         */
41:         struct _tn      *rnode;     /* pointer to right sub-tree        */
```

(Continued on page 106)

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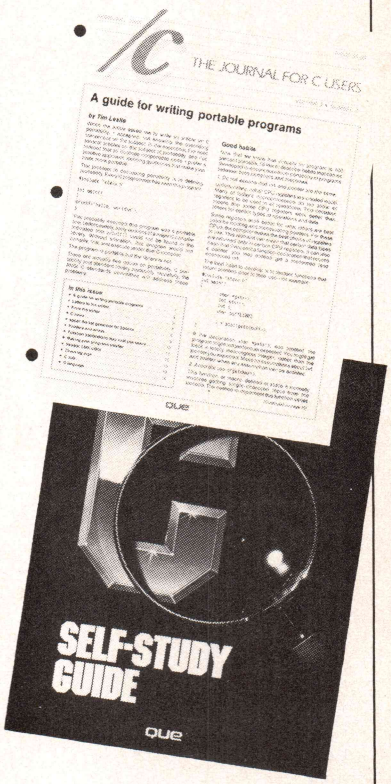

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```
42:         char            *being_made; /* name of file being made         */
43:         char            **depends_on;/* names of dependant files        */
44:         char            **do_this;   /* Actions to be done to make file */
45:         long            time;        /* time & date last modified       */
46: }
47: TNODE ;

48: /*-------------------------------------------------------------------------*/

49: static TNODE     *Root     = 0  ;        /* Root of file-name tree        */
50: static FILE      *Makefile      ;        /* Pointer to opened makefile    */
51: static int       Inputline = 1  ;        /* current input line number     */
52: static char      *First    = "" ;        /* Default file to make          */

53: extern char      *malloc();              /* From standard library         */
54: extern char      **getblock();           /* Declared in this module       */
55: extern char      *getline();             /* ditto                         */
56: extern TNODE     *find();                /* ditto                         */

57: /*-------------------------------------------------------------------------*/

58: char    *gmem( numbytes )
59: {
60:         /*      Get numbytes from malloc. Print an error message and
61:          *      abort if malloc fails, otherwise return a pointer to
62:          *      the memory.
63:          */

64:         extern  char    *calloc();
65:         char    *p;

66:         if( !( p = calloc(1,numbytes) ))
67:                 err("Out of memory");

68:         return p;
69: }

70: /*-------------------------------------------------------------------------*/

71: char    **stov(str, maxvect )
72: char    *str;
73: {
74:         /*      "Str" is a string of words seperated from each other by
75:          *      white space. Stov returns an argv-like array of pointers
76:          *      to character pointers, one to each word in the original
77:          *      string. The white-space in the original string is replaced
78:          *      with nulls. The array of pointers is null-terminated.
79:          *      "Maxvect" is the number of vectors in the returned
80:          *      array. The program is aborted if it can't get memory.
81:          */
82:
83:         char    **vect, **vp;

84:         vp = vect = (char **)  gmem( (maxvect + 1) * sizeof(str) );
85:         while( *str && --maxvect >= 0 )
86:         {
87:                 skipwhite(str);
88:                 *vp++ = str ;
89:                 skipnonwhite(str);
90:                 if( *str )
91:                         *str++ = 0;
92:         }

93:         *vp = 0;
94:         return( vect );
```

```
95: }

96: /*---------------------------------------------------------------------------*/

97: long    gtime( file )
98: char    *file  ;
99: {
100:        /*      Return the time and date for file.
101:         *
102:         *      The DOS time and date are concatanated to form one
103:         *      large number. Note that the high bit of this number
104:         *      will be set to 1 for all dates after 2043, which will
105:         *      cause the date comparisions done in make() to not work.
106:         *      THIS ROUTINE IS NOT PORTABLE (because it assumes a 32
107:         *      bit long).
108:         */

109:        static REGS     regs;
110:        short           handle = 0;     /* Place to remember file handle */
111:        long            time;

112:        gregs( &regs );
113:        regs.h.ah = OPEN ;              /* Open the file                 */
114:        regs.h.al = 0;                  /*      for read                 */
115:        regs.x.dx = (short) file ;

116:        if(  dos(&regs) & CARRY )
117:        {
118:                /* File doesn't exist. Return a huge date & time        */

119:                return DEFTIME;
120:        }
121:        else
122:        {
123:                handle    = regs.x.ax;
124:                regs.x.bx = handle;     /* Put file handle in BX        */
125:                regs.h.ah = DATETIME;   /* Get or set date and time     */
126:                regs.h.al = 0;          /* Get the date and time        */

127:                if( dos( &regs ) & CARRY )

128:                        err("DOS returned error from date/time request");

129:                time = ((long)( regs.x.dx ) << 16)  |
130:                                        ((long)( regs.x.cx ) & 0xffffL) ;

131:                regs.h.ah = CLOSE  ;    /* Close the file handle        */
132:                regs.x.bx = handle ;

133:                if( dos( &regs ) & CARRY )
134:                        err("DOS returned error from file close request");

135:                return time;
136:        }
137: }

138: /*---------------------------------------------------------------------------*/

139: TNODE   *makenode()
140: {
141:        /* Create a TNODE, filling it from the makefile
142:         * and return a pointer to it. Return NULL if there are no more
143:         * objects in the makefile.
144:         */

145:        char     *line, *lp;
146:        TNODE    *nodep;
147:        unsigned date, time;
```

(Continued on next page)

```
148:          /*      First, skip past any blank lines or comment lines.
149:           *      Return NULL if we reach end of file.
150:           */

151:          do{
152:                  if( (line = getline(MAXLINE,Makefile)) == NULL )
153:                          return( NULL );

154:          } while ( *line == 0 || *line == COMMENT );


155:          /*      A this point we've gotten what should be the dependancy
156:           *      line. Position lp to point at the colon.
157:           */

158:          for( lp = line; *lp && *lp != ':' ; lp++ )
159:                  ;


160:          /*      If we find the colon postion, lp to point at the first
161:           *      non-white character following the colon.
162:           */

163:          if( *lp != ':' )

164:                  err( "missing ':'" );   /* This will abort the program */
165:          else
166:                  for( *lp++ = 0; iswhite(*lp) ; lp++ )
167:                          ;

168:          /*
169:           *      Allocate and initialize the TNODE;
170:           */

171:          nodep              = (TNODE *) gmem( sizeof(TNODE) );
172:          nodep->being_made  = line ;
173:          nodep->time        = gtime( line );
174:          nodep->depends_on  = stov( lp, MAXDEP );
175:          nodep->do_this     = getblock( Makefile );

176:          return( nodep );
177: }

178: /*-------------------------------------------------------------------------*/

179: dependancies()
180: {
181:          /* Manufacture the binary tree of objects to make. First
182:           * is a pointer to the first target file listed in the
183:           * makefile (ie. the one to make if one isn't explicitly
184:           * given on the command line. Root is the tree's root pointer.
185:           */

186:          TNODE   *node;

187:          if( node = makenode() )
188:          {
189:                  First = node->being_made ;

190:                  if( !tree(node, &Root) )
191:                          err("Can't insert first node into tree !!!\n");

192:                  while( node = makenode() )
193:                          if( !tree( node, &Root ) )
```

```
194:                                    free( node );
195:                    return 1;
196:            }

197:            return 0;
198: }


199: /*---------------------------------------------------------------------------*/

200: char    *getline( maxline, fp )
201: FILE    *fp;
202: {

203:            /*      Get a line from the stream pointed to by fp.
204:             *      "Maxline" is the maximum input line size (including the
205:             *      terminating null. A \ at the end of line is
206:             *      recognized as a line continuation, (the lines
207:             *      are concatanated). Buffer space is gotten from malloc.
208:             *      If a line is longer than maxline it is truncated (ie.
209:             *      all characters from the maxlineth until a \n or EOF is
210:             *      encountered are discarded.
211:             *
212:             *      Returns: NULL on a malloc failure or end of file.
213:             *               A pointer to the malloced buffer on success.
214:             */

215:            static   char   *buf ;
216:            register char   *bp  ;
217:            register int    c, lastc;

218:            /* Two buffers are used. Here, we are getting a worst-case buffer
219:             * that will hold the longest possible line. Later on we'll copy
220:             * the string into a buffer that's the correct size.
221:             */

222:            if( !(bp = buf = malloc(maxline)) )
223:                    return NULL;

224:            while(1)
225:            {
```

(Continued on next page)

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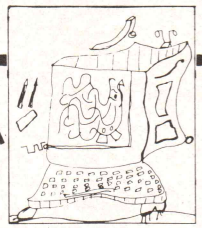

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```
226:                    /* Get the line from fp. Terminate after maxline
227:                     * characters and ignore \n following a \.
228:                     */

229:                    Inputline++;                    /* Update input line number     */

230:                    for( lastc=0; (c = fgetc(fp)) != EOF && c!='\n'; lastc = c)
231:                            if( --maxline > 0 )
232:                                    *bp++ = c;

233:                    if( !( c == '\n' && lastc == '\\' ) )
234:                            break;

235:                    else if( maxline > 0 )                  /* erase the \ */
236:                                    --bp;
237:            }
238:            *bp = 0;


239:            if( (c == EOF && bp == buf)  ||  !(bp = malloc((bp-buf)+1))  )
240:            {
241:                    /*      If EOF was the first character on the line or
242:                     *      malloc fails when we try to get a buffer, quit.
243:                     */

244:                    free(buf);
245:                    return( NULL );
246:            }

247:            strcpy ( bp, buf );     /* Copy the worst-case buffer to the one  */
248:                                    /* that is the correct size and ...       */
249:            free   ( buf );         /* free the original, worst-case buffer,  */
250:            return ( bp  );         /* returning a pointer to the copy.       */
251: }

252: /*-------------------------------------------------------------------------*/

253: char    **getblock( fp )
254: FILE    *fp;
255: {
256:            /* Get a block from standard input. A block is a sequences of
257:             * lines terminated by a blank line. The block is returned as
258:             * an array of pointers to strings. At most MAXBLOCK lines can
259:             * be in a block. Leading white space is stripped.
260:             */

261:            char    *p, *lines[MAXBLOCK], **blockv = lines ;
262:            int     blockc = 0;

263:            do {
264:                    if( !(  p = getline(MAXLINE,Makefile)  ))
265:                            break;

266:                    skipwhite(p);

267:                    if( ++blockc <= MAXBLOCK )
268:                            *blockv++ = p;
269:                    else
270:                            err("action too long (max = %d lines)", MAXBLOCK);

271:            } while( *p );


272:            /*      Copy the blockv array into a safe place. Since the array
273:             *      returned by getblock is NULL terminated, we need to
```

```
274:            *       increment blockc first.
275:            */

276:           blockv = (char **) gmem( (blockc + 1) * sizeof(blockv[0]) );
277:           movmem( lines, blockv, blockc * sizeof(blockv[0]) );
278:           blockv[blockc] = NULL ;

279:           return blockv;
280:   }

281:   /*-------------------------------------------------------------------------*/


282:   err( msg, param )
283:   char    *msg;
284:   {
285:           /*      Print the error message and exit the program.
286:            */

287:           fprintf(stderr,"Mk (%s line %d): ", MAKEFILE, Inputline );
288:           fprintf(stderr, msg, param );
289:           exit(1);
290:   }

291:   serr( msg, param )
292:   char    *msg, *param;
293:   {
294:           /*      same as err() except the parameter is a string pointer
295:            *      instead of an int.
296:            */

297:           fprintf(stderr,"Mk (%s line %d): ", MAKEFILE, Inputline );
298:           fprintf(stderr, msg, param );
299:           exit(1);
300:   }

301:   /*-------------------------------------------------------------------------*/

302:   make(what)
303:   char *what;
```

(Continued on next page)

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C Chest Listing (Listing continued, text begins on page 96)

```
{
        /*      Actually do the make. The dependancy tree is descended
         *      recursively and if required, the dependancies are
         *      adjusted. Return 1 if anything was done, 0 otherwise
         */

        TNODE       *snode;             /* Source file node pointer     */
        TNODE       *dnode;             /* Dependant file node pointer  */
        int         doaction = 0 ;      /* If true do the action        */
        static char *zero    = (char *)0;
        char        **linev  = &zero ;


#ifdef DEBUG
        static  int     recurlev = 0;   /* Recursion level              */

        printf("make (lev %d): making <%s>\n", recurlev, what );
#endif

        if( !(snode = find(what, Root)) )
                serr("Don't know how to make <%s>\n", what );


        if( !*(linev = snode->depends_on))  /* If no dependancys        */
                doaction++;                 /* always do the action.    */

        for( ; *linev ; linev++ )           /* Process each dependancy  */
        {
#ifdef DEBUG
                recurlev++;
#endif
                make( *linev );
#ifdef DEBUG
                recurlev--;
#endif

                if( !(dnode = find(*linev, Root)) )
                        serr("Don't know how to make <%s>\n", *linev );

#ifdef DEBUG
                printf("make (lev %d): source    file ", recurlev);
                ptime( what, snode->time );
                printf("make (lev %d): dependant file ", recurlev);
                ptime( *linev, dnode->time );
#endif
                if( snode->time <= dnode->time )
                {
                        /* If source node is older than (time is less than)
                         * dependant node, do something. If the times are
                         * equal, assume that neither file exists but that
                         * the action will create them, and do the action.
                         */
#ifdef DEBUG
                        printf("make (lev %d): %s older than %s\n",
                        recurlev, what, *linev );
#endif
                        doaction++;
                }
#ifdef DEBUG
                else
                    printf("make (lev %d): %s younger than %s\n",
                                                recurlev, what, *linev );
#endif
        }
```

```
358:          if( doaction )
359:          {
360:  #ifdef DEBUG
361:                  printf("make (lev %d): doing action:\n",
362:                                                  recurlev, *linev, what);
363:  #endif
364:                  for( linev = snode->do_this; *linev; linev++ )
365:                  {
366:                          printf("%s\n", *linev); /* Echo action to screen */
367:  #ifndef DEBUG
368:                          if( system(*linev) )
369:                                  serr("Can't process <%s>\n", *linev );
370:  #endif

371:                          /*      Change the source file's time to reflect
372:                           *      any modification.
373:                           */

374:                          snode->time = gtime( snode->being_made );
375:                  }
376:          }

377:  #ifdef DEBUG
378:          printf("make (lev %d): exiting\n", recurlev );
379:  #endif
380:          return doaction;
381:  }


382:  /*------------------------------------------------------------------------
383:   *      Tree routines:
384:   */

385:  TNODE   *find( key, root )
386:  char    *key;
387:  TNODE   *root;
388:  {
389:          /* If key is in the tree pointed to by root, return a pointer
390:           * to it, else return 0.
391:           */
```

(Continued on next page)

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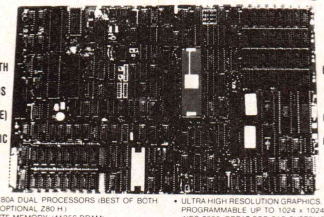

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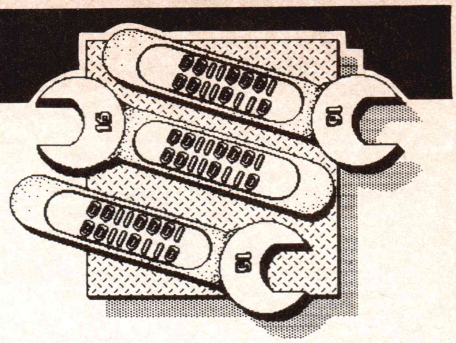
```
392:        register int    notequal ;
393:        register TNODE  *rval    ;

394:        if( !root )
395:                return 0;

396:        if( !(notequal = strcmp(root->being_made,key)) )
397:                return( root );

398:        return(  find( key, (notequal > 0) ? root->lnode : root->rnode) );
399: }

400: /*---------------------------------------------------------------------------*/

401: tree( node, rootp )
402: TNODE   *node, **rootp ;
403: {
404:        /* If node's key is in the tree pointed to by rootp, return 0
405:         * else put it into the tree and return 1.
406:         */

407:        register int    notequal ;
408:        register TNODE  *rval    ;

409:        if( *rootp == NULL )

410:        {
411:                *rootp = node;
412:                return 1;
413:        }

414:        if( !(notequal = strcmp( (*rootp)->being_made, node->being_made)))
415:                return 0;

416:        return( tree( node, notequal > 0 ? &(*rootp)->lnode
417:                                         : &(*rootp)->rnode)   );
418: }

419: /*---------------------------------------------------------------------------*/

420: main( argc, argv )
421: char    **argv;
422: {
423:        /*      A stupid version of the unix make utility.
424:         *
425:         *
426:         */

427:        if( !(Makefile = fopen(MAKEFILE, "r")) )
428:                err("can't open %s\n", MAKEFILE );

429:        if( !dependancies() )
430:                err("Nothing to make");
431:        else
432:                make( argc > 1 ? argv[1] : First );
433: }
434: #ifdef DEBUG
435: /*---------------------------------------------------------------------------
436:  *      Msc. Debugging routines
437:  */

438: ptime( file, t )
439: char    *file;
440: long    t;
441: {
```

```
442:          /* Print out the time and date field of a TNODE as
443:           *              "mm-dd-yy hh:mm:ss"
444:           * File is the file name.
445:           */

446:          int date, time;

447:          date = (t >> 16) & 0xffffL ;
448:          time = t & 0xffffL ;

449:          printf("%s: ", file );
450:          printf("%02d-%02d-%02d, ", (date >> 5 ) & 0x0f, date & 0x1f,
451:                                          80 + ((date >> 9) & 0x7f) );

452:          printf("%02d:%02d:%02d, ", (time >> 11) & 0x1f, (time >> 5) & 0x3f,
453:                                            (time << 1) & 0x3e  );
454:          printf("\n");
455: }

456: /*-------------------------------------------------------------------------*/

457: pnode( node )
458: TNODE *node;
459: {
460:          /*      Print out the tree node pointed to by "node"
461:           */

462:          char **linev;
463:          printf("+----------------------------\n");
464:          printf("|  node at 0x%x\n",                          node );
465:          printf("+----------------------------\n");
466:          printf("| lnode  = 0x%x,  rnode = 0x%x\n",node->lnode,node->rnode);
467:          printf("| time   = 0x%lx =",              , node->time          );
468:          ptime( "", node->time );
469:          printf("| target = <%s>\n"                , node->being_made    );
470:          printf("| dependancys:\n"                                       );
471:          for( linev = node->depends_on; *linev; printf("|\t%s\n", *linev++))
472:                  ;

473:          printf("| actions:\n" );
474:          for( linev = node->do_this; *linev; printf("|\t%s\n", *linev++))
475:                  ;
476:          printf("+----------------------------\n");
477: }

478: /*-------------------------------------------------------------------------*/

479: trav( root )
480: TNODE   *root;
481: {
482:          /*      Do an in-order traversal of the tree, printing the
483:           *      node's contents as you go.
484:           */

485:          if( root == NULL )
486:                  return;

487:          trav( root->lnode );
488:          pnode( root );
489:          trav( root->rnode );
490: }
491: #endif
```

End Listing

16-BIT SOFTWARE TOOLBOX



by Ray Duncan

Bug Report: TEE Filter

Dr. Fred Sinal of Hampton, Virginia, writes: "There is a slight bug in your listing of TEE in the April 1985 '16-Bit Software Toolbox' column. Actually the bug is in DOS, but that's life. If the file does not end with a CR/LF, we get a 'disk is full' message. DOS is forcing CR/LF to the console and confusing the character count. This problem may be covered up by eliminating the pair of lines

```
cmp ax,nchar
jne tee7
```

before the label **tee4**. Of course this reopens the disk full problem, when redirecting the standard output. I could not find a truly satisfactory fix."

Some Musings about DRI

Most of you have probably seen the recent splashy full-page ads for Digital Research's GEM that are appearing in nearly every magazine except *Sports Illustrated*. These ads lead you to believe that you can get a 16-color equivalent of Macintosh MacPaint for the IBM PC by just picking up GEM and GEM-Paint for a few pence at your corner computer store.

Beware: The fine print in the ad says "appropriate graphics hardware required." The appropriate hardware turns out to be the IBM Enhanced Graphics Adaptor, which will set you back about $1200 for the required controller board, memory expansion, and higher resolution RGB monitor. If you use GEM on an "ordinary" IBM graphics adaptor, the icons, windows, and all the rest are in vibrant black and white.

Speaking of Digital Research, look before you leap into spending any money on the product that DRI is advertising (with tongue in cheek, I'm sure) as "Concurrent PCDOS." It's concurrent, I guess, but it certainly doesn't resemble current versions of PCDOS. "Concurrent PCDOS" does not support the hierarchical file structure or any of the Unix-like executive services that are present in MSDOS or PCDOS versions 2 and 3. In other words, "Concurrent PCDOS" supports only the functionality of MSDOS or PCDOS version 1, which was more or less a clone of CP/M.

Thus, almost any of the more powerful MSDOS applications you are likely to buy will not run properly under "Concurrent PCDOS." Furthermore, a recent review in *PC Tech Journal* demonstrated that a set of programs run concurrently under "Concurrent PCDOS" will actually take longer to complete than if you simply run them consecutively under normal MSDOS. You can draw your own conclusions, but Digital Research's hopes of recapturing its old dominance of the personal computer operating system market seem more like delusions to me.

More on Square Roots

Tom Prince, of Marblehead, Massachusetts, writes:

"I was interested in your discussion of square rooting in the May 1985 column. A similar algorithm in 8088 code appeared in *Dr. Dobb's* over a year ago, encouraging me to add a floating point square root to my collection of Z80 code. Since the Z80 has enough registers to perform 32-bit calculations, it can do the square root much faster than the 8080 or even 8088 can do a floating point divide. Imagine my surprise to see an integer square root that takes ten times as long as a divide, even when coded in assembler! Even a conversion to floating point to take the root ought to be faster.

"So I wrote up the following code for a well-known '32-bit' processor. It turns out to be slower than sqrt(float( )) but certainly doesn't take ten times as long as an integer divide. Of course it takes longer than the three integer divides that are included and would run faster if coded in assembler. Would it be too much to ask to provide high-level language versions of routines like these that work perfectly well, if a bit slower?"

Mr. Prince's code can be found in Listing One (page 122).

Mac Fan Strikes Back

Mr. S. Allen, of Ojai, California, writes:

"I am, and have been for quite a while, an ardent admirer of *DDJ*. I have been hard-pressed to find a magazine of such technical excellence aimed at the more advanced computer user.

"I do, however, have a GRIPE! I was quite excited when you began the 16-Bit Toolbox. I expected to find droves of information on the latest hardware innovations and the support software to go with them. You can imagine my chagrin when I discovered a thinly disguised 'The IBM PC is Wonderful' column. To call the IBM PC, with its 8088, a 16-bit machine is pushing things a little, and then to have the writer launch irrational tirades against a true 16-bit machine (the Mac) lit my Bulls—t High Level Light.

"Please, be honest. If you are going to have an IBM PC column, call it that. If you are going to have a 16-bit column, let's have it be about 16-bit machines. From reading the present 16-Bit Toolbox, I must assume that the writer is either in IBM's or Intel's pocket. Your magazine has a long-standing reputation for impartiality. I implore you, do not destroy it."

Well, I suspect that the flip-flop

controlling Mr. Allen's Bulls—t High Level Light is in need of replacement. Let me first assure *DDJ* loyal readers that I am not in either IBM or Intel's pocket. If I were, I'd ask them for a suitably monstrous amount of money, retire, and pass this column on to other younger and more energetic souls.

People who actually read this column know that it is heavily devoted to reports of bugs in Microsoft, IBM, or Intel products, so that programmers can work around them. These bug reports hardly constitute advertisements for the companies involved (except, I guess, for those who have the philosophy that any publicity is good publicity). I defy anyone to look back at the previous columns and anywhere find the message "The IBM PC is Wonderful."

As for our emphasis on the Intel 8086 family of microprocessors and the MSDOS operating system, these remain the dominant force in the personal computer world and seem likely to remain so for the forseeable future; consequently, they are of primary interest to those of us who write programs for a living. Whether the 8088 is really a 16-bit processor or not is a moot point; it runs the same machine code as the 8086, it acts like an 8086, and it is everywhere. Quibbling over the bus width is a waste of our time.

We certainly are interested in extending our coverage of other 16-bit processors, and as people who actually read this column will also know, we have given considerable coverage to the 68000 and Macintosh over the last few months and will continue to do so as long as our readers indicate an interest in it.

Regarding 68000 Assemblers

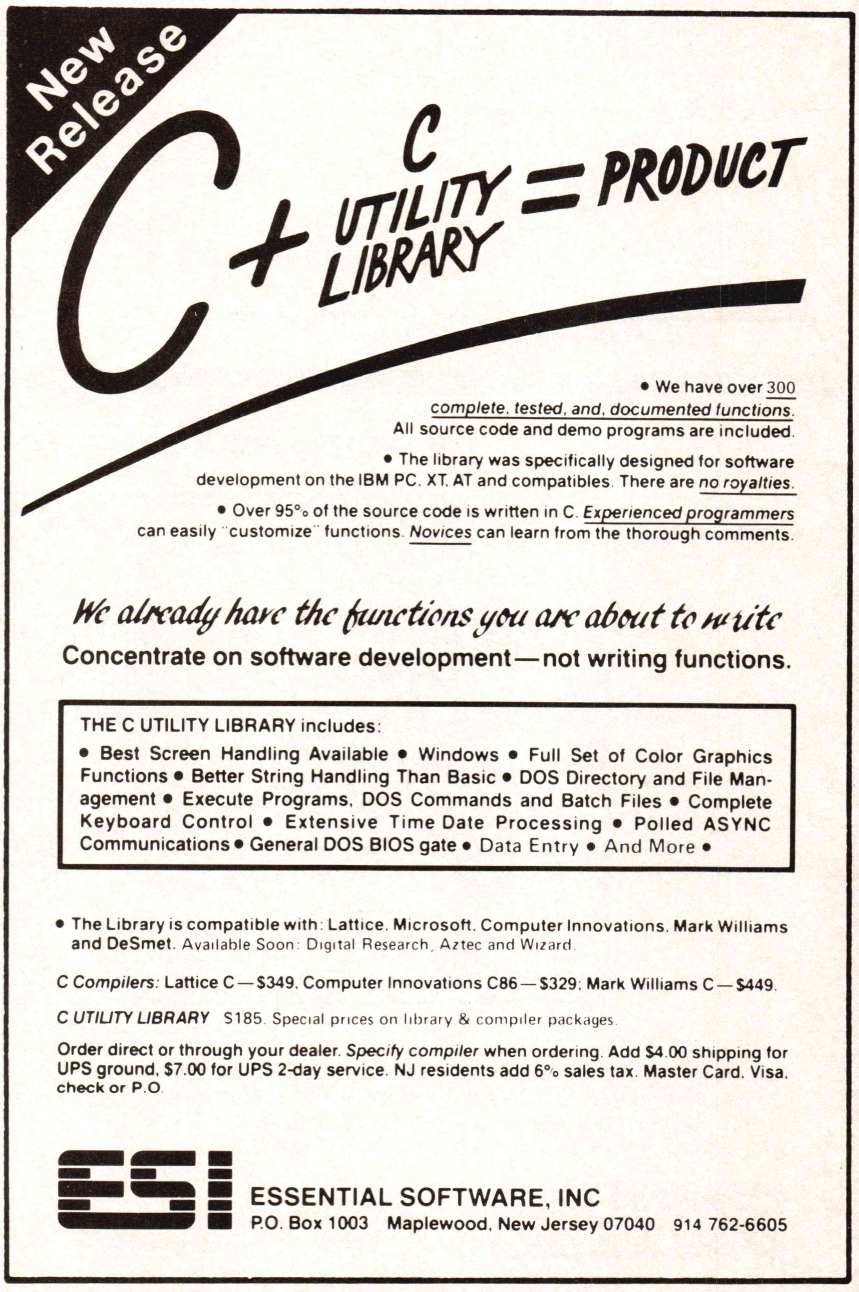
Mr. Michael Aichlmayr, of Tacoma, Washington, writes:

"In regards to Mr. Howell's remarks in your May 1985 column, I would like to add myself to the list of people who feel it is truly possible to build an efficient assembler for the 68000—one that would run in a reasonable amount of memory and execute in a productive amount of time.

"I don't feel that the 68(x)xx family is nearly as complicated as Mr. Howell implies. I think elegant simplicity is a more accurate statement. Any good programmer could make great use of generic addressing modes and instructions. I think I would hazard to go so far as to say that I believe it could be done in C and run in 64K on a 68(x)xx processor (the horrible overhead of the [Intel] 80(x)xx would make it a real challenge). I have a 6809 assembler written in C that runs easily in 64K of memory on every machine for which it is compiled.

"It's very sad to realize that the abundance and low cost of memory have given programmers an excuse to be gross and inefficient. I have seen code that could run in my HP 29C calculator take up more than 64K of memory and 'require' a 128K IBM PC or compatible to run. It makes me think that if a machine came standard with a megabyte of RAM, someone would come up with a desk calculator that would hog the machine.

"Mr. Howell remarks that he has a 6809 system that he likes better than his IBM compatible. I direct his attention to the TSC (Technical Systems Consultants) 68000 macro assembler. I have been able to coax the assembler to run in 32K on a 6809



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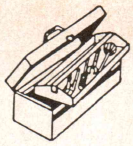

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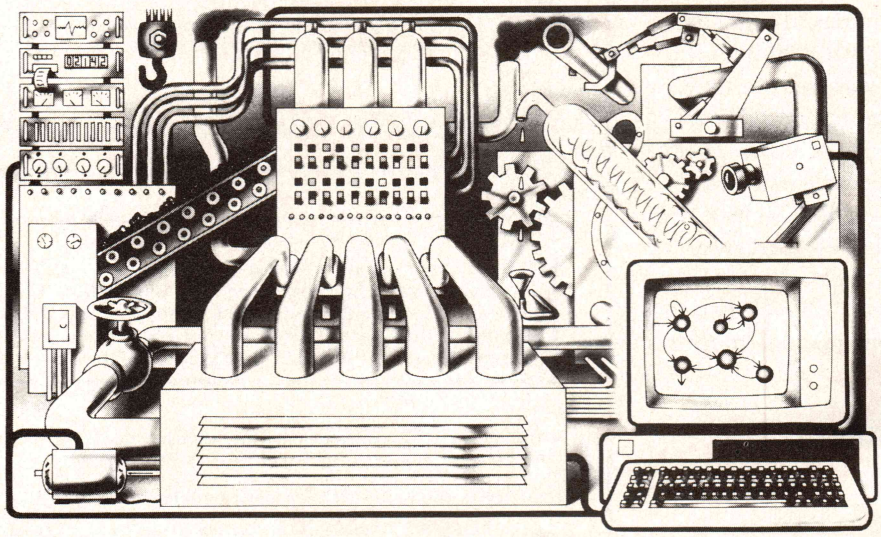

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system running under the FLEX operating system. I realize it does not produce relocatable object modules; however, that piece of code would be fairly small given the architecture.

"Having a 6809 machine (which I built), a Mac (which I tolerate), and a DG One IBM compatible (which I use), I think I can safely assume that I have some knowledge of hardware and software. I find it very aggravating that IBM chose the 80(x)xx architecture over that of the 68(x)xx, but I have never seen a processor more crippled than that in the Mac.

"I eagerly await the arrival of the Atari ST, which I have had the opportunity to play with for a while. If all appearances are correct, this is a good use of a 68000. The machine runs at 8 MHz, has 32K [of RAM devoted to] memory-mapped color graphics, and is said to come standard with 512K of RAM for $699.00! I'm not sure what the GEM OS is going to do to the thing since I have little regard for DRI, but it doesn't look bad so far."

More Mac Feedback

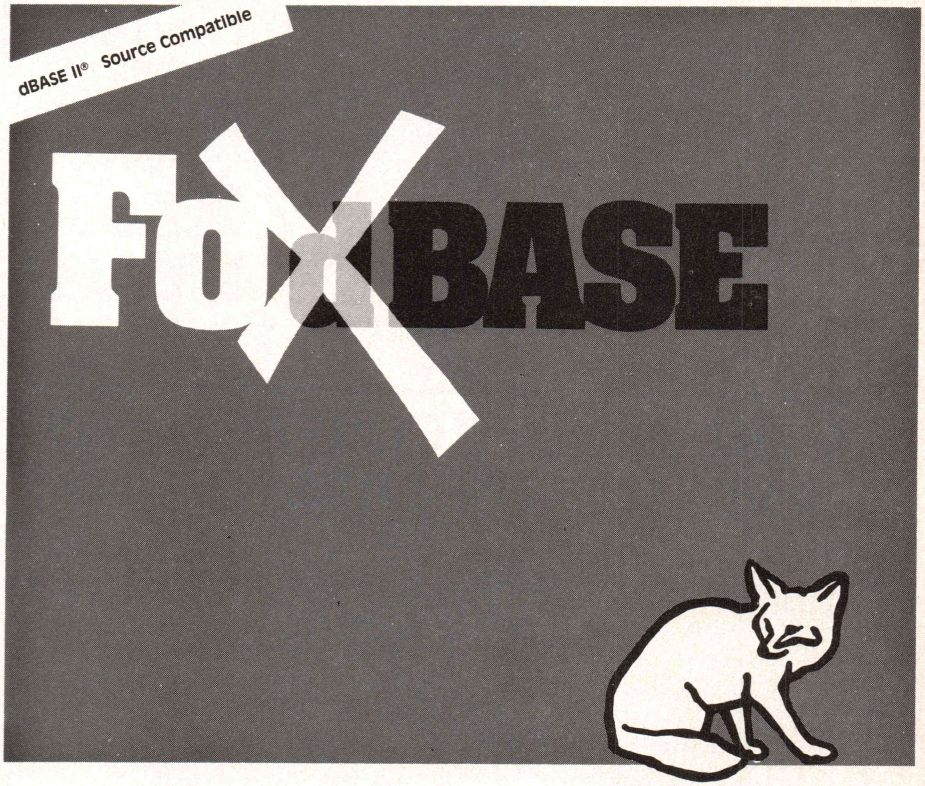
Kirk Kerekes, of Tandata Inc., in Tulsa, Oklahoma, submitted a thoughtful and interesting letter:

"As circumstances seem to have started a debate in your column *re* the Mac as a development environment, I felt it appropriate to provide some facts to fuel the debate and perhaps redirect it to more substantive issues.

"FACT: There is no assembler that I know of for the Mac that requires the use of two (or more!) Macs. This myth has been floating around for quite a while and was recently mentioned in your column. This myth doubtless arises from the fact that there are two Apple-issue debuggers that use a second computer as a control device to allow undisturbed screen displays on the system being debugged. As there are around half a dozen debuggers that do *not* require a second unit, and at least one of the two-machine debuggers will use *any* reasonable terminal as a remote controller, I see no reason to regard this situation as anything but a blessing for the developer. The debuggers are available as part of the Inside Mac supplement program and are distributed as a group.

"If you are doing development on the Mac and are a fan of debuggers, then the $100 price tag of the supplement could be justified for them alone. (I've gotten at least $100 worth of micro-floppies through my supplement subscription, just valued as media!)

"FACT: There are numerous complete, stable high-level languages for the Mac. A recent glance reveals at least three Forths, half a dozen Cs, a Pascal or two, Microsoft BASIC, and NEON, an object-oriented Forth-like language. I can state that at least one product of a professional nature, MegaMax C, is 'real,' well-supported, and quite clean. Assembler fans can obtain the MacAsm mentioned in your column or ask almost anybody for a copy of the prerelease versions of the Apple Editor/Assembler/Linker/Resource Compiler package. By the time this might see print, the official release of the MDS+Inside Mac package should have occurred. This package is already on the certified developer's price list. The price is lower than any complete serious development environment available for



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MSDOS.

"FACT: The bloated size of most of the early Mac applications is the result of the use of Lisa Pascal as the development environment. There is absolutely nothing about the Mac that requires/generates bulky code. I have created useful Mac-interface programs with a load module size less than 1K using the MegaMax C compiler. An 'empty' C program (i.e., main( ) {}) yields a load module of about 300 bytes. Most of this appears to be information that any application stores for use by the Finder. I just tried the same experiment with Computer Innovations C86 under MSDOS and got a 5K EXE file result, due to C86's insistence on loading the standard I/O library whether or not it is invoked.

"POINT: Nobody at Apple denies that the Mac concept, from mouse on up, is derived from the Xerox PARC research. The point in the Mac is to take the PARC concepts and implement them in an affordable machine. Go price a Xerox Star and then price a Mac (first, *find* a Star!)." [As this column went to press, Xerox announced a new incarnation of the Star, the model 6085, that costs $4995 with 1 Mb of RAM, 10 Mb hard disk, a 15-inch display, and a mouse . . . . RD]

"OPINION: I develop professionally on MSDOS, CP/M, and Mac systems. I use the major development products in each environment for both C and assembly language. It is my opinion that there are better development environments available for the Mac than for MSDOS or CP/M. The Mac development products tend to be less expensive, too. There are also some real losers available for all these environments. I'm not going to name names; we all have our own favorite turkeys.

"OPINION: There are a number of programming professionals who feel threatened by the Mac. It is not my purpose to speculate why this should be the case. It *is* my purpose to assert that no professional need feel threatened by the Mac. With the tools currently available, it is a joy to develop on, and there are enough 'goodies' in the system toolbox to keep just about anybody happy. There is definitely a learning curve involved, enough of one to be a barrier to dabblers, but anyone familiar with good modern programming practices can produce useful programs in very short order. The Mac environment punishes sloppy programming practices and greatly rewards programmers who plan thoroughly before they code.

"Maligning the Mac is not going to make it go away. Being annoyed by Steve Jobs or marketing hype is not realistic. The only tool Apple has to battle IBM in the public mind is flamboyance. Steve Jobs' opinions may not be yours, but you know his name, *Playboy* readers know his name, and an amazingly large percentage of the general public knows his name. Now, what is the name of the CEO of IBM? Of *any* officer of IBM? See how it works?

"I propose that further discussion of development on the Mac actually center on development on the Mac . . . not on myths and spurious side issues! There is plenty to discuss, believe me!"

In reply, I only question whether the only tool Apple has to battle IBM is flamboyance. The tried and true tools of delivering quality products on time seem to have served some companies pretty well (such as Compaq, which has taken on IBM head-on and is doing better than Apple at it in many respects). The rest of Mr. Kerekes' points are well taken, and indeed we will try to stick to substantive discussion of the Mac in the future. By the way, the CEO of IBM is John Akers (last I heard); although this fact probably *isn't* a part of the general knowledge of the average *Playboy* reader, it is fairly common knowledge in the computing community.

Reading about the Mac

I have run across two recent articles about the Macintosh that are both helpful and balanced (unlike the rabid pro or con articles that are prevalent in the popular computer press).

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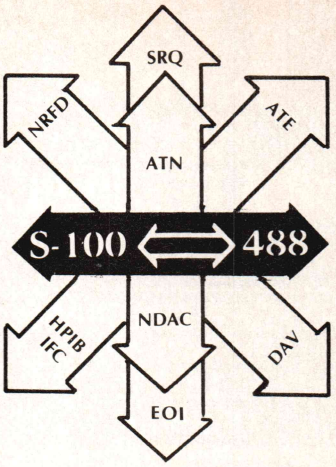

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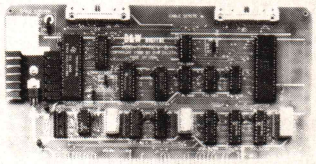

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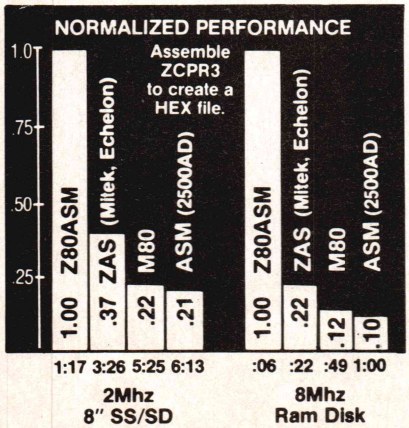

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The first is simply a detailed, objective, nonhysterical review of the Macintosh written by Larry Press of Small Systems Group; this review appeared in *Abacus*, Vol. 2, No. 2 (Winter 1985), page 51. The author is an experienced computer user with no particular fish to fry who is oriented toward the use of the Macintosh in educational contexts.

Abacus, by the way, is an intriguing publication that shows signs of developing into a unique and useful magazine. The quality of writing is high, the percentage of advertisements low, there is virtually no boosterism of "in" computers or software products, and the magazine is eclectic. The issue mentioned contained articles on human computers (how calculating prodigies perform arithmetic), a report on personal computers at Amos Tuck School, an exposition of "The Applicative Style of Programming," a review of the special *Scientific American* issue on software, and a report by chess master David Levy on a match between himself and CRAY BLITZ (winner of the 1983 World Computer Chess Championship). *Abacus* is published by Springer Verlag New York Inc., a source of scientific and academic texts.

The second notable article is "Apple Macintosh Software" by Dr. Ted Lewis of the Computer Science Department of Oregon State University, published in *IEEE Software*, March 1985, page 89. This is a combination review and tutorial of "the coding standards and methods forced upon application programmers who accept the challenge of writing applications for the Macintosh." It includes a simple example program with pull-down menus and an explanation of the structure and contents of the resulting "resource file." This article is the first reasonable explanation I have seen of this subject and is orders of magnitude more comprehensible than the Apple documentation.

Dr. Lewis concludes: "The ideas and techniques incorporated into the Macintosh software are admirable, but I am struck by the boldness of Apple Computer. Programming a Macintosh is not easy for conventional programmers, and this has contributed to the slow appearance of Macintosh software. Does Apple expect everyone to change? Do they think that a technical achievement like the Macintosh is inducement enough to persuade programmers to wade through 800 pages of *Inside Macintosh* merely to discover the merits of object-oriented programming and Desktop?

"The Macintosh software is unconventional, nonstandard, and probably horribly nonportable. The dialect of Pascal used is related to UCSD Pascal, but there is little hope of separating it from the Macintosh ROM routines. Yet, the software is nearly a work of art; all objects are organized in a logical and concise manner. The notion of a resource file is powerful and will most likely be emulated by programmers everywhere."

DDJ

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```
function isqrt(i)
                integer*4 i,js #32 bits
                byte j1(4)
                equivalence(js,j1(1)) #with reversal, j1(4) is high byte of js
#you didn't take care of zero and negative arguments!
                js=i
                #count high order 0 bits 8 at a time
                for(k0=0;j1(4)==0;k0=k0+8)js=ishft(js,8) #shift left 8 bits
                for(;js>0;k0=k0+1)js=ishft(js,1) #count remaining 0 bits
                #get initial approximation within 50%
                isqrt=ishft(3,ishft(31-k0,-1)-1) #3*2**((29-k0)/2),not for i=1
                do k=1,3 #improve by Newton iterations
                        isqrt=ishft(i/isqrt+isqrt,-1) #(i/isqrt+isqrt)/2
return
end
```

Listing One
Tom Prince's square root algorithm

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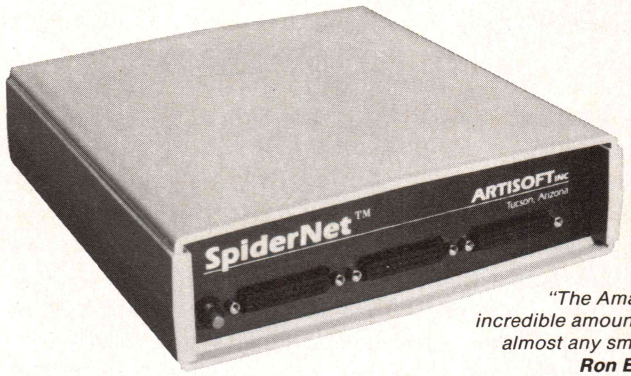

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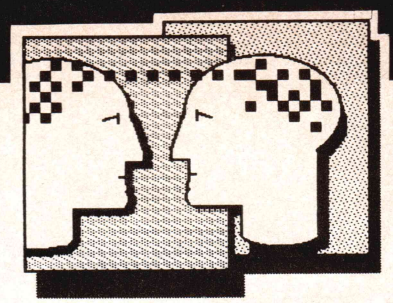

by Robert Blum

The CP/M Exchange RCP/M system is available for your use 24 hours a day, 7 days a week. Reach it by dialing (404) 449-6588.

Online . . . at Last

For more than two years I have been promising to bring up a RCP/M system in support of this column—finally, it's online. I hope you will participate in its use and share with me your thoughts on how I can improve it.

To reach it, call (404) 449-6588 any hour of the day or night, seven days a week. The modem is a Racal-Vadic 3452, which is capable of communicating at either 300 or 1200 baud. The other hardware components are an Ampro single-board Z80 microcomputer driving two 5¼-inch Teac floppy disk drives and a 20 Mb hard disk drive. This configuration should be more than adequate, at least for the present, to support the amount of activity that I anticipate.

The main purpose of the system is to provide improved access to the information printed in this column. The complete text of all the programs and updates printed here will be available for downloading. I hope this will stimulate even more reader participation in the column by providing a convenient method for submitting items of interest. I will also maintain a current list of all known CP/M bug reports and any fixes that might be available; this includes application notes and fixes published by DRI.

When your call is answered, hit the return key several times to indicate the baud rate you are using. Next you will be asked whether your terminal needs nulls for proper operation. Once beyond these two preparatory steps, you will enter into the message system. From this point on, I think the system is self-prompting enough to get you started without requiring a lengthy tutorial.

If you call to transfer program files, enter a "J" at the main menu prompt to jump to CP/M. Once under CP/M control, execute the MAP transient program to get a system map, which will guide you around the system.

Rather than spend a lot of time talking here about what you can expect when calling my RCP/M system, I suggest that you pick up your phone and call. Again, please leave a message outlining your impressions of the system and any improvements that you might want to suggest.

The Free Software Catalog and Directory

Public domain software is software that legally can be copied, used, and given to another user without payment of a royalty to its author.

Estimates project that over 40 Mb of program source code are contained on the 300+ volumes of CP/M public domain software. In this vast library can be found just about any type of utility program that you might need to help manage your CP/M system. A number of business application programs, mostly written in CBASIC, are present as well.

Until now, many would-be public domain software freaks have been defeated by the thought of searching through over 5000 program titles to find just the few desired. Fortunately, Robert A. Froehlich, a long-term member of SIG/M and an avid user of public domain software, foresaw this problem and has compiled a reference book detailing and indexing each program.

The Free Software Catalog and Directory is a 475-page 8½ x 11-inch book printed on newsprint stock. It focuses on the two largest and most readily available free software libraries, the CP/M Users Group (CPMUG) and the Special Interest for Microcomputers (SIG/M), while providing all the information necessary for personal computer owners to take advantage of this resource.

The introduction begins by setting aside any fears one might have about using public domain software. It concludes by talking a little about the main sources of free software. But most important is the elaborate tutorial—the best I have seen—for successfully completing a session with a remote bulletin board system (BBS). This section in itself makes the book a worthwhile investment for the novice and experienced user alike. The remainder of the introduction prepares the reader for dealing with source code files and explains how to go about making changes to them, should that be necessary.

The real meat of this book is contained in the next six sections. Every file in the entire 92-volume set of the CPMUG library and the first 162 volumes of the SIG/M library is described in detail. The first and second sections, the largest of the six, include complete information for each file as follows: filename, size in Kbytes, CRC checksum, date of entry, language if program source code, author's name, revisor's name, file title, keywords assigned to the file, and finally a textual description of the file.

Of course, the main purpose of this book is to provide ready access to information about the routines or programs of interest to you. The next four sections cross reference each file alphabetically by keyword, language type, author name, and filename. For example, if you want to find a program to compare two files for equality, your initial search might start in the keyword section under utilities. You find there two entries. If the one

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for comparing binary files sounds like it would serve well, note the reference: SIG/M volume 115. You can then track down a complete description of the chosen file by referring to the second section of the book, which covers the SIG/M volumes.

As if all this weren't enough, the book concludes by listing several hundred user groups and bulletin board systems by name, location, and phone number.

This book has become the most used of any in my bookcase. It is a tremendous bargain at $9.95. The author has accomplished a phenomenal task in both compiling this much material and cross indexing it for ease of access. Whether you are an individual user of free software or the librarian of a user group, you will benefit from having this book.

If you're having trouble finding a source of free software in your local area, call the "CP/M Exchange" RCP/M system at (404) 449-6588 for a list of user groups where public domain software can be found.

8088: 8- or 16-bit Processor?

The following paragraphs, taken from the introduction to the Intel *iAPX 88 Book*, set the record straight on how the manufacturer intended the 8088 to be classified:

"This book describes the unique Intel 8088 microprocessor, the outstanding choice for 8-bit microcomputer applications requiring both high performance and low cost.

"The Intel 8088 is the most powerful 8-bit microprocessor available today, yet as easy to use as other 8-bit microprocessors designers have used for years."

Outside of the marketing rhetoric, these two paragraphs contain the phrase "8-bit" often enough to dispel any doubt that the 8088 was designed as an 8-bit processor.

Exiting Properly to CP/M

Two accepted methods for returning to CP/M from an application program are documented by DRI in the CP/M 2.2 reference manual. Although both are said to achieve the same result, in practice they react very differently and, depending on the situation, can cause a great deal of frustration.

Steve Russell of SLR Systems brought this incompatibility to my attention. In the process of testing one of his assemblers, he stumbled onto a difference between exiting to CP/M by jumping to memory location zero (BOOT) and by calling the BDOS with a System Reset function. The problem occurred when he tried executing several assemblies through a submit file in conjunction with XSUB. The first assembly finished successfully, but all the others failed because for some reason XSUB was no longer active after the first assembly.

Apparently, the documentation wasn't updated when XSUB was released. When loaded, XSUB's first action is to relocate itself immediately under the CCP and to modify the BOOT address so that it no longer points to the BIOS jump table but to the XSUB warm start routines. This modification is necessary so that XSUB can trap any further warm start requests to avoid having to reload memory with a fresh copy of the operating software. Thus, XSUB remains resident and active. But if the BDOS is called with the System Reset function, a fresh copy of the operating software is immediately loaded without checking whether XSUB or a similar program is active.

Because XSUB was designed for use within SUBMIT batch procedures, the result of a program returning to CP/M via the BDOS reset call is that suddenly XSUB no longer remains active: the BOOT vector stored at memory location 0 has been reset, and a fresh copy of the operating software is loaded. Any other programs in the same procedure that depend on XSUB to provide console input from the batch file will then fail to execute as planned.

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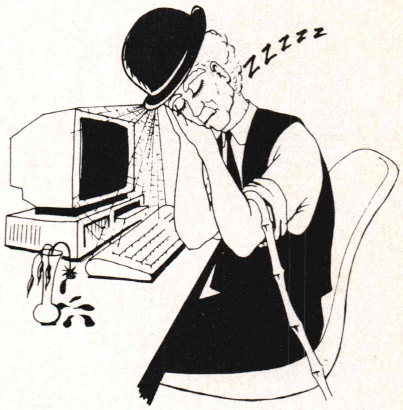

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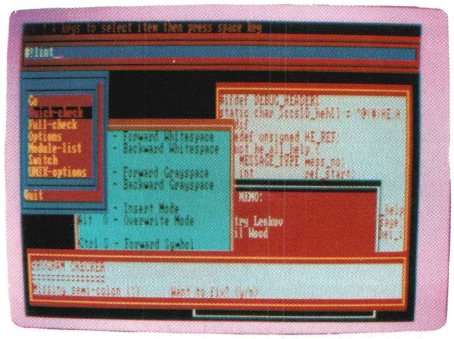

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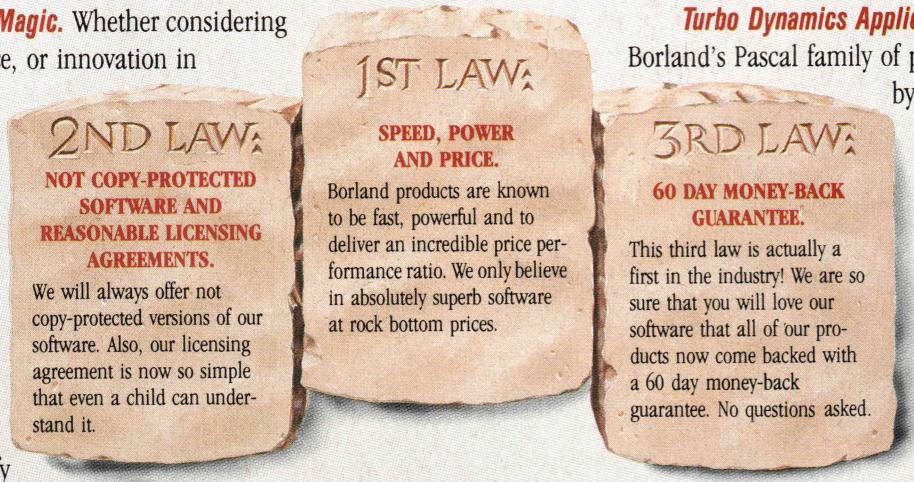

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